Revised Final Draft
Use of Best Available Science
in City of Mukilteo Buffer Regulations

Prepared for
City of Mukilteo

March 10, 2004
12174-03

PENTEC ENVIRONMENTAL
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Revised Final Draft
Use of Best Available Science
in City of Mukilteo Buffer Regulations

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ACRONYMS

BAS	Best available science
CAO	Critical areas ordinance
City	City of Mukilteo
CTED	Washington State Department of Community, Trade and Economic Development
Ecology	Washington State Department of Ecology
ESA	Endangered Species Act
FEMAT	Forest Ecosystem Management Assessment Team
GMA	Growth Management Act
LWD	Large woody debris
MMC	Mukilteo Municipal Code
NMFS	National Marine Fisheries Service
OHWM	Ordinary high water mark
SEPA	State Environmental Policy Act
SMA	Shoreline Management Act
SMP	Shoreline Master Program
SPT	Site potential tree
UGA	Urban growth area
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDW	Washington Department of Wildlife (now a part of WDFW)

EXECUTIVE SUMMARY

The Growth Management Act (GMA) requires that municipalities include best available science (BAS) in their critical areas ordinances (CAO) to protect the functions of critical areas. Criteria determining what constitutes BAS are specified by the Washington State Department of Commerce, Trade, and Economic Development (CTED) in the Washington Administrative Code (WAC 365-195-900 *et seq*). Many other goals and objectives are specified in the GMA including directives to focus growth within the urban growth areas where there is the infrastructure to support it. Another goal is to prevent urban sprawl into more rural areas that do not have the infrastructure to support such growth.

The City currently uses, and will continue to use a multi-tiered approach to protect designated critical areas. The existing and proposed CAO both use buffers as a primary means to protect functions of critical areas. However, the Shoreline Master Program, zoning regulations, storm water management requirements, and other development regulations are used together in concert with the CAO to protect these valuable resources. Enforcement of the CAO, State Environmental Policy Act, and other regulations, as well as monitoring are and will continue to be an important part of Mukilteo's multi-tiered program to protection of the existing functions that critical areas provide.

Changes have been proposed to the existing CAO. Many of these have been developed in cooperation with the Washington State Department of Ecology (Ecology). Others have been adopted to be consistent with other regulations. For example, proposed wetland and stream classification systems have been modified. The City proposes to adopt Ecology's four-tiered wetland classification system. Another proposed modification is adoption of the Washington Department of Natural Resources stream typing system as promulgated in WAC 222-16-031.

At the recommendation of Ecology, permitted use provisions of the proposed CAO have been strengthened to reduce potential impacts to wetlands by eliminating buffer reduction for lots less than 10,000 square feet. Buffer reduction would only be allowed under the reasonable use provisions. Many other provisions, such as buffer averaging and various allowed low impact uses in buffers remain in the proposed CAO, pursuant to approval of a special study by the Planning Director. Other proposed revisions include modifications to required buffers are based on the functions provided by the critical areas, BAS regarding the critical area protection provided by buffers, and on existing conditions in the City of Mukilteo (City).

Wetlands, streams, shorelines, and other critical areas in the City have been altered by historical and on-going land use and development and are influenced by extant physical processes and characteristics (climate, geology, topography). The physical characteristics of the landscape have contributed to the existing physical, chemical, ecological and biological characteristics and existing functions of the critical areas and their buffers. In general, functions of wetlands, streams, and shorelines and their associated buffers have been degraded. Although critical areas and their buffers continue to provide some level of ecological function, the levels of function provided are generally lower than those provided by critical areas and buffers in less disturbed or developed areas. This appears to be particularly true of biological functions in part because of habitat simplification and fragmentation. According to the published scientific literature, the effects of habitat fragmentation on biota are varied and do not appear to be well understood particularly as this phenomenon pertains to highly developed urban areas. In general, this appears to have reduced habitat complexity and productivity favoring flora and fauna that have broader ecological tolerances (i.e., generalists) over those species with more specific (i.e., specialists) habitat requirements.

In Mukilteo, one of the most important functions of both wetlands and streams appears to be protection of surface water quality because these critical areas receive stormwater runoff from urban areas that likely contains elevated levels of pollutants. Because of the existing geology and topography, many of the wetlands in the City are depressional types. Some of these are located in the headwater areas of streams and likely are important in reducing the amount of pollutants contributed to streams. This function may be limited by the hydraulic residence time and pollutant transformation and retention processes in these systems. Although the biological communities of streams have been degraded, some streams continue to support anadromous salmonids. Both wetlands and streams have some net positive effect on nutrient and pollutant removal and maintenance of water quality and productivity in Puget Sound.

Wetland, stream, shoreline, and steep slope buffers help protect the functions of existing critical areas. In addition, the vegetated buffers, where they exist can provide a variety of functions protecting or enhancing the quality of habitat and ecological function in critical areas. Buffer functions include sediment removal, nutrient removal, bacteria, pathogen, and toxicant removal, shade and temperature modification, creation of microclimates, contribution to wildlife habitat and trophic structure (large woody debris [LWD], energy inputs, and food web dynamics), and shoreline stabilization. The level of critical area protection provided by buffers depends on many factors, including the size and nature of the critical area, existing land uses, topography, geology, and biological characteristics of the buffer. The level of protection provided is quite variable as shown by the wide range of widths cited in the scientific literature for the performance of various functions. The effectiveness of buffers at providing the various functions is summarized in the text, figures, and tables provided.

In Mukilteo, existing and historical development has altered the physical, chemical, biological, and ecological characteristics of buffers adjacent to critical areas. In general, this has resulted in low to moderate effectiveness of buffer protection provided to critical areas; for example water quality protection can be compromised where stormwater runoff is bypassed through the buffer directly to wetlands and streams. There are a few notable exceptions. For example, perhaps the most effective existing buffers are those along streams flowing in steep, vegetated ravines. Contributions to trophic structure and habitat stability, water quality, and wildlife habitat functions appear to be the most important functions of buffers adjacent to critical areas in the City. Smaller buffers than those suggested in the model CAO guidelines published by CTED appear to be warranted to protect the existing functions of the generally small and degraded critical areas in the City. Proposed buffers and their anticipated effectiveness at providing key functions based on the BAS are summarized in Table 1. This report provides details on the various buffer functions and relevant BAS used to develop this table in relation to critical area conditions in Mukilteo.

USE OF BEST AVAILABLE SCIENCE
IN CITY OF MUKILTEO BUFFER REGULATIONS

1.0 INTRODUCTION

1.1 Mandates of State Law and Why Buffers are Being Revised

The Growth Management Act (GMA) requires local governments to include best available science (BAS) in their record and to consider it substantively in developing critical areas policies and regulations. The GMA also requires local governments to balance more than a dozen goals and several specific directives in implementing those goals. The GMA provides local governments with the authority and obligation to take scientific evidence and to balance that evidence among the many goals and factors to fashion locally appropriate regulations. The GMA gives great deference to a local government's substantive outcome in this balancing process.[1]

The Washington State Department of Community, Trade and Economic Development (CTED) (formerly Office of Community Development) has promulgated regulations dealing with the use of BAS in the designation and protection of critical areas and resource lands. The BAS regulations (WAC 365-195-900 *et seq.*) state:

1. *To demonstrate that BAS has been included in the development of critical areas policies and regulations, counties and cities should address each of the following on the record:*

    a. *The specific policies and development regulations adopted to protect the functions and values of critical areas at issue.*

    b. *The relevant sources of BAS information included in the decision making.*

    c. *Nonscientific information - including legal, social, cultural, economic, and political information - considered as a basis for departing from recommendations derived from BAS.*

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1. For a more detailed discussion of the Best Available Science requirement, see HEAL v. Growth Management Hearings Board, 96 Wn. App. 522 (1999).

This document identifies existing mechanisms for protection of streams and wetlands; provides an overview of existing and proposed portions of the Critical Areas Ordinance (CAO) for protecting streams and wetlands; identifies existing buffer and stream and wetland functions; and presents an analysis of the effectiveness of existing compared to proposed stream and wetland buffers for protecting stream and wetland functions.

1.2 Overview of the City's Existing and Proposed Regulatory Requirements for Buffers

1.2.1 Measures to Protect Habitat, Shorelines, and Critical Areas

As described in Section 1.1, local governments are required to use BAS in developing their CAO. These regulations use numerous tools to protect critical areas and their functions, of which buffers are one tool. These tools work together with other regulatory requirements to protect the functions of critical areas. It would not be practicable to evaluate the effectiveness of buffers or to establish minimum buffer width requirements without also taking into consideration other regulations that protect the functions described in Section 2.

The City of Mukilteo has a multi-tiered approach to protecting the ecological functions of riparian and estuarine habitat areas. These are developed mainly through a public, interagency decision-making process and become regulatory through their adoption into the City's comprehensive plan (including its Shoreline Master Program [SMP]) and the City's zoning code (including its shoreline use regulations) and other development regulations. This multi-tiered approach includes the following:

- Establishment of land uses in designated areas to avoid or reduce the potential for land use conflicts.

- Establishment of land uses and densities that encourage urban infill to avoid and reduce pressure on development in critical areas within the urban area, and natural or rural areas outside of the urban area.

  For example, certain areas that have been the focus of urban development are designated for higher-density residential land use.

- Establishment of performance standards for specific activities or uses to control emissions that would adversely affect ecological functions.

These regulations are developed through a public, interagency decision-making process and become regulatory through their adoption as development regulations in the City's code, including, for example, as CAO; stormwater and pollution prevention; erosion control; noise, light, and glare control; numerous shoreline uses; and similar regulations.

- Establishment of narrative criteria for siting of development or control of impacts from land and shoreline uses and activities.

  These regulations are developed through a public, interagency decision-making process and become regulatory through their adoption as policies in the comprehensive plan and shoreline program or as development regulations in the City's code, including, for example, numerous shoreline use policies and regulations, CAO requirements and criteria for assessing and conditioning projects, development of required plans to protect environmentally sensitive areas and resources, and State Environmental Policy Act (SEPA) substantive policies.

- Establishment, monitoring, and enforcement of project conditions.

  This typically occurs through the project review process under RCW 36.70B and City code, including SEPA and public review. This involves establishing protective conditions and often includes monitoring and/or enforcing permit conditions and City codes. Most projects subject to public and environmental review have protective conditions required of them to control emissions or impacts to, and ensure compatibility with, critical area resources.

Consequently, a buffer is not the only – or necessarily the most effective – tool to protect the functions discussed in Section 2. For example, as discussed later in this report, standards for runoff and erosion control are likely to be more effective than buffers in controlling sedimentation. Landscape and revegetation plans required for permits for redevelopment projects are likely to be more effective in producing a desired multistoried riparian canopy to provide shade, detrital input, and insect fall than a buffer requirement that simply sets back a development from a critical area, without revegetation. In developed and developing areas, stormwater regulations are likely to be more effective than a wider buffer in protecting and ensuring water quality.

The use of BAS means focusing on effective tools to maintain or improve the functions provided by the critical area or shoreline, and should not assume that a buffer requirement is the only effective tool or that a buffer works in isolation from other tools that are being employed.

1.2.2 Shoreline Management Act

The Shoreline Management Act (SMA) provides for the management of the shorelines of the state by planning for and fostering all reasonable and appropriate uses. The SMA states a policy preference for uses that are consistent with the control of pollution and prevention of damage to the natural environment, single-family residences, ports, shoreline recreational uses, public access facilities, and industrial and commercial developments that are particularly dependent upon use of the state's shorelines. The City's incorporation of its CAO into its SMP implements the SMA policy of preventing damage to the natural environment while fostering preferred uses.

1.2.3 City of Mukilteo Municipal Code Title 17, Chapter 52: Critical Areas Regulations – Existing and Proposed

1.2.3.1 Classifications for Wetlands and Streams – Existing and Proposed

The existing City of Mukilteo CAO uses a three-tiered system to classify wetlands (17.52B.090). Wetlands are given a designation of Type I, II, or III based on a number of factors, including the presence of rare wildlife species, ecological significance, size, and vegetation communities, among others. Existing buffers are 100, 50, and 25 feet, respectively, but may be increased on a case-by-case basis depending on site-specific conditions.

If proposed changes are adopted, the CAO would classify wetlands using the Washington State Department of Ecology's (Ecology's) Wetland Rating System for Western Washington (Ecology 1993). The Ecology system classifies wetland into four Categories (Category I, II, III, or IV). Brief descriptions of the categories are provided in Table 2. Ecology is currently revising this document. The revised document is expected to include rapid functional assessment methods for estimating the functions wetlands provide. It is likely that the City will adopt any subsequent revisions of this document pertaining to the classification and evaluation of wetland functions.

The existing CAO (17.52C.090) uses a three-tiered system to classify streams (Class I, II, and III) under the existing Fish and Wildlife Habitat Regulations. Required buffers for these are 100, 75, and 25 feet, respectively. The City maintains discretion to increase buffer requirements depending on site conditions or requiring rehabilitation of degraded Class III stream as a condition of project approval per Mukilteo Municipal Code (MMC) 17.52C.100.C.

To be consistent with the state, the City has proposed to adopt the Washington State Department of Natural Resources stream typing classifications as provided in WAC 222-016.031, Interim Water Typing System. Streams would be designated Type 1, 2, 3, 4, or 5. Brief descriptions of the stream types are provided in Table 3. Using the state's system for classifying streams will enable the City to adjust required buffers to more closely resemble the state's recommendations. City of Mukilteo streams and wetlands are shown on Figure 1.

1.2.3.2 Buffer Requirements – Existing and Proposed

The CAO requires buffers around critical areas, including wetlands, streams, steep slopes, and shorelines. Required wetland and stream buffer widths are determined by the classification of the wetland or stream or presence of steep slopes or shorelines. Existing and proposed buffer requirements are shown for wetlands in Table 4 and for streams in Table 5. Because the proposed changes to the CAO use different systems for classification of wetlands, a direct comparison of buffer requirements is difficult. Direct comparison between existing and proposed buffers is also difficult because of changes in the classification system for streams. One comparison can be made between Class II and Type 2 streams because both of these classifications are for the highestquality streams in the City. Comparing the existing buffer requirements for Class II streams (75 feet) with the buffer for proposed Type 2 streams (100 feet), it is clear that buffer requirements have increased for the highestquality streams and would be expected to be more protective of associated functions. For almost all streams in the City, buffers would be even larger as at least portions of each are associated with ravines that meet the definition of steep slope (>40%). Buffer requirements for streams are further strengthened in the proposed CAO by the addition of a minimum of a 25-foot construction setback from the top-of-slope for any stream within a steep slope area (most of the ravines in the City). As shown on Figure 2 (to be included in the Final Draft), this has the practical effect of increasing the buffer for Type 2 and 3 streams within steep ravines.

Increase or Reduction of Standard Buffer Width. For wetlands and streams, standard buffer widths may be increased or reduced under certain circumstances. Wetland buffers may be reduced by 25 percent for single-family lots less than 10,000 square feet per the provisions in MMC 17.52B.100.C. Wetland buffer width averaging and reduction also are allowed per MMC

17.52B.100.D. 1 through 3. These provisions allow buffer reductions up to 50 percent but in no case to less than 25 feet. Buffers of less than 50 feet provide relatively nominal levels of some functions, such as water quality protection (see Section 3.2 for a more detailed discussion of buffer functions). In addition, some portions of the code, such as the Exemptions (MMC 17.52B.040), Public Agency and Utility Exceptions (MMC 17.52B.050), and Reasonable Use Provisions (MMC17.52B.180) do not appear to maintain sufficient buffers to protect all wetland functions (see Section 2.1 for more details). However, these provisions are clearly made in consideration of other objectives allowed under GMA, such as focusing and supporting growth within designated urban growth areas (UGAs) as well as other legal tenets.

Based on the proposed changes to the CAO, required wetland buffers may be increased by the City if, after a site-specific analysis, it is found that: (1) sensitive species or habitats occur in the wetland or if adjacent land is susceptible to severe erosion, (2) the standard buffer width has minimal or degraded vegetation, (3) a wetland extends into an area with a slope of greater than 25 percent, or (4) sensitive fish and wildlife species or habitats would be impacted. Buffers might be increased if a site-specific study suggests that a standard buffer may not be protective enough of existing wetland functions.

Stream buffers may also be reduced or averaged subject to the provisions set forth in MMC 17.52C.100D and E. Under no circumstances may buffers be reduced by more than 50 percent of the required buffer or less than 25 feet. Depending on existing stream size and functions, and on buffer conditions, a buffer of 25 feet may be quite protective of stream functions. The Exemptions (MMC 17.52C.030), Public agency and utility exception (MMC17.52C.040) and Reasonable use provisions (17.52C.160), may allow smaller than standard buffers and likely would not be as protective as standard buffers of all of the functions provided by streams (see Section 2.2 for more details of stream functions). However, these provisions appear to take into consideration other goals and objectives of GMA (i.e., focusing growth within the UGAs) as well as heeding state and federal constitutional rights pertaining to private property.

Under the proposed CAO, there are more restrictive and protective provisions pertaining to single-family resident lots less than 10,000 square feet and buffer reduction. The exemption for single-family resident lots has been eliminated. In addition, buffer reduction may only be allowed by approval of the Planning Director through the reasonable use exception process.

Permitted Uses within Buffers. Existing legal uses are permitted in all buffers. In addition, low impact uses may be permitted in the buffers of wetlands and streams subject to a special study completed by a qualified specialist that demonstrates no net loss of critical area function or value, and that public health and private property would not be at risk. Such proposed low impact uses must be approved by the Planning Director. In general, these uses are restricted to the outer portion of the buffer as far away from the critical area as possible per MMC 17.52B.100.E (Wetlands) and 17.52C.100.F (Streams), 17.52. Low impact uses that may be allowed in wetland and stream buffers per existing code may include:

- Pedestrian trails;
- Viewing platforms;
- Some stormwater management facilities, such as grass-lines swales;
- Utility easements when no other alignment or option is available; and
- Utilities when no other alignment or option is available.

Existing and ongoing agricultural uses, which can be a significant source of non-point pollution including nutrients, fecal coliform bacteria, and other pollutants are exempt from both wetland and stream regulations per MMC 17.52B.040.A.1 and MMC 17.52C.030.A.1. These are limited and allowed only with conditions. These provisions are similar to those suggested in CTED's Model CAO. They would only be approved by the Planning Director following demonstration that the proposed uses would not adversely affect existing critical area functions.

1.3 Report Objectives and Organization

The City of Mukilteo's proposed SMP relies on the City's GMA CAO (Mukilteo Municipal Code Title 17, Chapter 52) to accomplish a number of its objectives. To document its consideration of BAS in its decision-making, the City has funded this examination of the existing and proposed buffers in the City's CAO.

This report identifies the City's existing and proposed definitions of wetland categories and stream types and existing and proposed standard buffer requirements (Section 1.2.3.1). Section 2 reviews the state of scientific knowledge with regard to wetland, stream, and shoreline functions, emphasizing those functions of greatest importance within the UGA. Section 3 summarizes the BAS regarding wetland, stream, and shoreline buffer functions. Section 3 summarizes the functions of buffers, and the actual buffer functions of greatest concern for each aquatic habitat type are identified along with factors that may modify those buffer functions in Mukilteo. Finally, Section 4 summarizes the effectiveness of proposed buffers at providing the riparian functions that are key to each aquatic habitat type in the City.

2.0 BAS FOR WETLAND AND STREAM FUNCTIONS

This section integrates the state of the knowledge on the BAS regarding wetland, stream, and shoreline functions. Much of the scientific literature is for more pristine ecosystems or from research done in other parts of the country, and it is uncertain how this information applies to functions of wetlands, streams, and shorelines in Washington. While many of the ecological, chemical, biological, and physical processes may be similar, the rates and processes may be somewhat different given the specific climatic, geological, and biological circumstances in the highly altered urban areas in Mukilteo.

2.1 Wetlands

Wetlands are widely recognized as both providing functions and having values. Functions are generally characterized as the ecological, biological, chemical, and physical processes that occur in wetlands. By contrast, values are perceptions assigned to wetlands by human society. Not all functions performed by wetlands are valued by people and some functions are valued more than others. In addition, wetlands may be perceived as more or less valuable because of their location, physical and biological characteristics, position in the landscape, or other attributes. Functions are performed at many different scales ranging from microscopic to broad geographic areas and have been defined by many different authors, including Adamus et al. (1987), Brinson et al. (1995), Hruby et al. (1999), and Keddy (2000). Some of the broad functions often attributed to wetlands include:

- Fish and wildlife habitat;
- Water quality protection;
- Groundwater recharge/discharge;
- Flood water storage and attenuation or desynchronization.

Adamus et al. (1991) suggest that functions can generally be grouped into one of three broad categories:

- Biogeochemical functions, such as nutrient cycling and pollutant removal;

- Hydrologic functions, such as contributing to surface water flows in a watershed or reducing flooding; and

- Energy flow and habitat functions, such as primary and secondary production and contributing to biological diversity.

In their synthesis of the science related to wetlands and their protection, Ecology (Sheldon et al. 2003) has identified 15 major functions within these three categories for wetlands in Washington. Many of these have been identified and defined as part of Ecology's development of Washington State Function Assessment Methods (Hruby et al. 1999 and 2000). Although wetlands perform many types of functions, not all wetlands perform all functions, nor do similar wetlands provide the same level of function (Clairain 2002). Functions provided by wetlands depend on many factors, including position in the landscape, physical structure, and surrounding land uses. In addition, wetlands are dynamic (changing) systems, and functions may vary naturally over time, especially food web support and wildlife habitat in response to changes in vegetation structure and disturbances in the wetlands watershed or contributing basin area that may alter the hydrologic regime. Disturbance, natural and human generated, may control or drive changes in the physical structure of wetlands, which in turn affects the functions they provide (Dale et al. 2000). In addition to disturbance, these authors give an excellent review of other ecological principles (e.g., time, space, place, and landscape) and guidelines for land use.

Some functions, including maintenance of populations of commercially important fish and wildlife, are important economically at local, regional, and global scales.

2.1.1 Water Quality Protection

Ecology (Sheldon et al. 2003) has subdivided the water quality protection functions into a number of classes of materials sequestered or removed, including sediment, phosphorus, nitrogen, metals, and toxic organic compounds. The interested reader is referred to Ecology's synthesis of the science (Sheldon et al. 2003) for a more detailed assessment of the processes that affect the removal rates for each of these constituents. All of these constituents are naturally occurring but considered pollutants when elevated above natural background levels as a result of urbanization or development. Elevated concentrations of each of these constituents can contribute to water quality degradation and/or adverse effects to aquatic flora and fauna. When considering the water quality protection function of wetlands, it is important to understand that many pollutants, such as nutrients, metals, and organics (pthalates and polycyclic aromatic hydrocarbons) have a tendency to adsorb or become attached to sediment. These are considered particulate forms and can be removed by mechanical settling or filtration. For example, much of the copper, lead, and zinc, the most common trace elements or heavy metals found in urban runoff in national and local studies, are associated with suspended sediments (EPA 1983; Galvin and Moore 1982). By contrast, dissolved forms are less easily removed by microbial degradation, sequestration by plants, formation of complexes with dissolved organic substances, or other processes. Up to 40 percent of the copper and zinc in urban runoff can be in dissolved forms (Galvin 1987).

The effectiveness of wetlands in removing both particulate and dissolved forms of pollutants is variable. In addition, removal rates are not constant but vary seasonally and are dependent on numerous factors, including pH, temperature, hydraulic residence time, dissolved oxygen, pollutant loading rates, wetland structure, and the assimilation capacity of the wetlands (e.g., see review by Desbonnet et al. 1994). In any case, for wetlands to be effective at protecting water quality, they must receive pollutants from surface water runoff from surrounding development or atmospheric deposition (wet or dry). Some wetlands, especially depressional and some riverine flow-through hydrogeomorphic classes, may be quite effective at removing pollutants and protecting water quality by removing suspended sediments and their associated pollutants. Removal of dissolved forms of pollutants, especially nutrients, may be provided during the growing season through plant uptake or denitrification processes. However, unless the above-ground biomass of plants (especially grasses, sedges, rushes, and forbs) is harvested, wetlands can be a source of nutrients to downstream areas as nutrients and metals are recycled or remineralized through decomposition processes or they transform from insoluble to soluble forms as nutrient-rich sediments become anaerobic (Kulzer 1990; Adamus et al. 1991).

As indicated by Ecology (Sheldon et al. 2003), not all wetlands in a region, class, or subclass perform all functions. Depressional, riverine, slope, and lacustrine (lake) fringe class wetlands have been identified by Ecology as providing sediment removal function. Removal of sediment also removes particulate fractions of pollutants adsorbed to sediments. The value of sediment and pollutant removal functions is difficult to quantify but they are clearly important and may be dependent on conditions (e.g., loading rates) in a given watershed and the quality of receiving waters. The value of this function may be highest for streams and rivers that support economically important fisheries or pollutant-sensitive (intolerant) biota and, therefore, may be landscape position dependent. All wetlands appear to be important at some level in protecting the biological diversity and integrity of aquatic resources.

2.1.2 Hydrologic Functions

Wetlands in Washington provide a number of hydrologic functions, including water storage that reduces peak flows, decreasing downstream erosion, and recharging groundwater (Sheldon et al. 2003). Reducing peak flows and downstream erosion are flood control functions provided by wetlands that receive stormwater runoff from developed areas. Wetlands reduce peak flows and erosion in streams and rivers by slowing and storing water that would otherwise flow more rapidly downstream and cause more severe flooding (Reinelt and Horner 1995). This process is also known as flood desynchronization (Hruby et al. 1999). The value of this function may be highest for wetlands upstream of developed areas susceptible to flooding. None of the wetlands in Mukilteo appear to provide high levels of flood control given the location of the small independent drainages and their direct discharges to Possession Sound and Port Gardner. Flood desynchronization is particularly dependent on wetland structure, especially flood storage capacity and vegetation. Riverine and depressional wetland classes appear to provide the highest potential function. However, slope and flats wetland classes also likely contribute to the cumulative flood desynchronization in a watershed, but perhaps to a lesser degree.

Groundwater recharge and discharge are other hydrologic functions of wetlands. Many freshwater wetlands in the County are groundwater discharge areas, especially slope and depressional wetlands that appear to receive much of their water from shallow groundwater. This phenomenon is common where there is a thin mantle of Alderwood series or other soils on top of glacial till and groundwater flowing along the contact between the overlying soil and underlying till on slopes emerges in the wetlands. Recharge of underlying aquifers may occur in some wetlands. As indicated by Ecology (Sheldon et al. 2003), factors affecting recharge include head pressure in the wetland, hydraulic conductivity of wetland soils and sediments and geologic deposits between the wetland and any underlying aquifers. For recharge to occur there must be hydraulic continuity between the wetland and any underlying aquifer. There appears to be little empirical data on the groundwater recharge function of wetlands in western Washington. Considering that hydric soils often tend to have low hydraulic conductivities, it appears that wetlands with low hydraulic conductivities likely provide little groundwater recharge. Hruby et al. (1999, 2000) concluded that groundwater recharge occurs only in depressional and riverine wetlands that impound and hold surface water. They reported that hydrogeomorphic types that do not impound surface water do not have the potential to recharge groundwater. As indicated by Adamus et al. (1991), it appears more likely that undeveloped uplands are usually more important than wetlands in recharging groundwater. This is likely particularly true where there are soils and underlying geologic deposits with high hydraulic conductivities, such as Everett gravelly sandy loam series soils and advance and recessional outwash deposits.

2.1.3 Trophic Structure and Wildlife Habitat Functions

It is well recognized that wetlands are very productive habitats that contribute to energy flow, food web dynamics, and support of biological diversity. Net primary production in wetlands, especially in tidal saltmarshes and freshwater marshes composed primarily of emergent plants, is among the highest of all ecosystems in the world (Gore 1983; Mitsch and Gosselink 2000). This production dictates the trophic structure and provides energy flow to consumers, thus contributing to the productivity of higher trophic levels. As indicated by Ecology (Sheldon et al. 2003), wetlands support many species some of which are wetland dependent and others that are wetland users.

Many species of fish and wildlife are wetland-dependent, requiring wetlands to complete all or a portion of their life cycle (Mitsch and Gosselink 2000; Brown 1985). Such species include beaver, muskrat, mink, various aquatic invertebrates, marsh wren, Pacific tree frog, rough-skinned newt, red-legged frog, long-toed salamanders, western pond turtle, and others. Without wetlands, these species would be unable to reproduce and sustain viable populations. There are no known occurrences of western pond turtle in Mukilteo. The other wetland-dependent species, with the possible exception of beaver and mink, are common in the City. Implementation of and compliance with mitigation requirements should avoid or minimize loss of wetlands and potential impacts to wetland-dependent species. In addition, maintaining connectivity to other habitats and sensitive areas will reduce potential further habitat fragmentation and associated impacts to wetland-dependent species, such as potential creation of isolated populations.

Many other species of mammals, birds, and reptiles are wetland users that may forage or rest in wetlands but do not require them to complete their life cycles. These species can be referred to as generalists that may take advantage of the habitats present in wetlands but that are capable of surviving and sustaining viable populations through use of other aquatic and terrestrial habitats. Animals that occasionally use wetlands as a source of food or drinking water (Adamus et al. 1991) are included in this group of wetland users. Some authors (e.g., Hruby et al. 1999; Brown 1985) have used loosely defined terms, such as "wetland-associated" to describe species known to use wetlands. Others (Brown 1985) have shown that more than 86 percent of identified species using forest habitats in western Washington and Oregon (359 of 414) are directly associated with one or more of the plant communities in riparian zones or wetlands during some season(s) or part(s) of their life cycles. Knutson and Naef (1997) reported that over two-thirds of all terrestrial vertebrate species in Washington can be considered to be wetland-dependent or wetland users.

Among the factors that affect habitat use are structural complexity, size, connectivity to other habitat, and adjacent land uses (see review by Knutson and Naef 1997). Many species of birds and mammals appear to be relatively intolerant of high levels of human activity, domestic animals, or habitat simplification and fragmentation that typically accompany urbanization. Other species appear to be more opportunistic and adaptable and appear to benefit from habitat alterations created by humans (e.g., coyote, raccoon, English (house) sparrow, house finch, European starling, opossum). Domestic animals, including dogs and cats, prey on or harass wildlife. Ground-nesting birds and small mammals appear to be particularly susceptible to predation by domestic animals, especially cats (Dunn and Tessaglia 1994). Milligan (1985) found that bird species richness in urban wetlands in King County was strongly correlated with buffer width and condition. Wetlands with larger and less disturbed buffers of at least 50 feet supported higher species richness. Consequently, many of the wetlands in Mukilteo that have high levels of human development or activity, are isolated by or surrounded by development, or have existing buffers of less than 50 feet, and therefore may only support species tolerant or adapted to such conditions.

Amphibians appear to be one of the exceptions to this and have been found to persist in wetlands with minimal buffers at diversities similar to those in larger and more structurally complex wetlands in the Puget Lowlands (Azous and Horner 2001). Although amphibian diversity can be high in urban wetlands, it is uncertain whether populations of amphibians can be self-sustaining, especially in the absence of adequate buffers for adult dispersal to other habitats. Richter and Azous (2001) have indicated that forested buffers as large as 1,640 feet are used as dispersal areas and may be critical to the maintenance of species richness. Others also have indicated the importance of dispersal corridors leading to other wetlands or upland habitats as being important to the maintenance of amphibian populations. These corridors also may be important for recolonization after populations have been lost to natural processes such as drought or disease (Pounds and Crump 1994; Bradford 1991) or pollution.

In addition to supporting a unique assemblage of fauna, wetlands support many species of plants specifically adapted for life in saturated soils. The physical and chemical characteristics of wetlands associated with different hydrologic regimes (timing, depth, duration, and frequency of inundation) result in floral assemblages found nowhere else on the landscape. Some species of plants exhibit relatively broad tolerances to environmental conditions and are commonly found in both wetland habitats and terrestrial habitats, such as red alder *(Alnus rubra),* black cottonwood *(Populus balsamifera* ssp. *trichocarpa),* salmonberry *(Rubus spectabilis),* and soft rush *(Juncus effusus);* however, others are found almost exclusively in wetlands. Wetland scientists, ecologists, and botanists have developed a database of observations and assigned an "obligate" wetland indicator status to those plant species that have a very high probability (99 percent) of occurring only in wetlands. The wetland indicator status of plants found in wetlands is published in a database maintained by the U.S. Fish and Wildlife Service. Probabilities associated with a given indicator status (e.g., OBL, FACW, FAC, FACU, etc.) are identified in Table 1 of the Washington State Wetlands Identification and Delineation Manual (Ecology 1997). Obligate wetland plants include such species such as diamond-leaf willow *(Salix planifolia),* narrow-leaf burreed *(Sparganium emersum),* slough sedge *(Carex obnupta),* giant manna grass *(Glyceria grandis),* and many other species. A number of other species are rare and/or endemic to wetlands, including water lobelia *(Lobelia dortmanna),* bog laurel *(Kalmia microphylla),* and whitebeak rush *(Rhynchospora alba)*. Smoky mountain sedge *(Carex proposita)* and Choris' bog-orchid *(Plantanthera chorisiana)* are the only plant species listed by the state as threatened that are known to occur currently in Snohomish County. Neither of these species is likely found in wetlands within Mukilteo.

Based on perhaps the most comprehensive study of urban wetlands in the Puget Sound region (Azous and Horner 2001), at least some species of wetland plants appear to be sensitive to changes in wetland hydrology that can result from urbanization (e.g., changes in the depth, duration, and frequency of inundation). Considering the amount of development and hydrological alterations that have already occurred in Mukilteo, it seems unlikely that many or possibly any sustainable populations of such species exist in Mukilteo.

By contrast, invasive species are common in wetlands with altered hydrology (e.g., common cattail, purple loosestrife, and reed canarygrass). These species are common in at least some of the wetlands in Mukilteo and may have already displaced at least some native plants in these disturbed wetlands. In addition, these particularly successful species likely threaten the continued viability of populations of native plants in such ecosystems. It is well recognized that non-native or invasive species that act as focal-species can exert a pronounced effect on ecosystems by altering productivity, habitat structure, and thereby other functions. For example, Dale et al. (2000) note that keystone species affect ecosystems through processes such as competition, mutualism, dispersal, pollination, and disease and by modifying habitats and abiotic factors. Common cattail, purple loosestrife, and reed canarygrass appear to act in this manner in many wetlands in urban or urbanizing areas in the City where these species form monotypic or nearly monotypic assemblages.

2.2 Streams

Streams are defined as those areas where naturally occurring surface waters flow sufficiently to produce a defined channel or bed, which demonstrates clear evidence of the passage of water. This evidence may include, but is not limited to, bedrock channels, gravel beds, sand and silt beds, and defined channel swales. A defined channel or bed means a watercourse that is scoured by water, or contains observable deposits of mineral alluvium. The channel or bed need not contain water during the entire year. Streams provide a variety of functions for anadromous and resident fish including salmonids. Streams also support a variety of wildlife species and contribute to the formation of wetlands and specific (e.g., riparian) vegetative communities.

The definition of streams as critical areas does not include water courses that were created entirely by artificial means, such as irrigation ditches, canals, roadside ditches or storm or surface water runoff features, unless the artificially created water course conveys a stream that was naturally occurring prior to the construction of the artificially created water course. This definition may vary from that used by Washington Department of Fish and Wildlife (WDFW) in administering the Hydraulic Project Approval (HPA) program.

All drainages within Mukilteo are relatively small and independent, that is they discharge directly to Possession Sound or Port Gardner. These drainages have been altered by historical and existing development but still provide some functions. Streams are displayed by stream type on Figure 1. The ecological functions of larger streams in Snohomish County, such as the Snohomish, Snoqualmie, and Skagit Rivers, have been well documented, most recently in products of the Snohomish Basin Salmon Recovery Technical Committee (SBSRTC 1999 and 2002). The smaller more altered drainages in Mukilteo would be expected to provide lower levels of some of these functions.

The formation and underlying morphology of streams in the western slopes of the Cascade Mountains are the product of the area's geologic, glacial, and climatological history (Pentec and NW GIS 1998). These historical factors and the more recent influences of vegetation and human disturbances continue to shape the streams in Mukilteo. King County (2003), in its draft BAS review has correctly pointed out the varied influence of riparian and landscape factors on instream functions as stream size increases. For example, riparian vegetation has a much greater influence in moderating the temperature of smaller streams such as those in Mukilteo than it does in larger streams (Beschta et al. 1987; Naiman et al. 1992).

The role of streams as critical areas centers around their functions in support of resident and anadromous fish and other species adapted to life in moving (lotic) waters. Streams are, first of all, necessary (almost by definition) for anadromous fish as a migration route between estuarine and saltwater rearing areas and spawning grounds (or hatcheries) in fresh water. The spawning function of stream habitat has perhaps the most specific environmental requirements for gravel quality, supply, and stability; water quality, velocity, and depth; and hydrology, especially intragravel flow. Streams also provide essential rearing area prior to migration to the marine environment; depending on the species of anadromous fish, stream rearing periods can range from a few days to 1 to 2 years (see reviews in Groot and Margolis 1991). Different species require (or at least prefer) different instream habitat characteristics for rearing, but all require good water quality and generally cool temperatures. Only Japanese Gulch, Big Gulch Creek, Picnic Creek, and Lunds Gulch Creek support anadromous fish species in Mukilteo.

In addition to functions for anadromous fish, streams provide a wide range of other ecological and social functions. Many species of wildlife including birds, mammals, and amphibians occur exclusively or primarily where flowing surface waters are accessible to them. Streams also convey water and create floodplains in a manner that allows the existence of some wetlands and recharges groundwater supplies. Streams convey sediment and, over time, have created small deltas that persist outside of the railroad tracks that cross all the stream mouths in the City. Historical and existing alterations to the hydrology of Mukilteo's streams have generated increased volumes of stormwater runoff. This, coupled with reduced areas of riparian vegetation have contributed destabilization, incision, and reduced habitat complexity. As a result, many of the smaller streams in Mukilteo appear to provide limited habitat opportunities or functions for aquatic biota.

The SBSRTC (2002) has described the condition of 62 sub-basins comprising the Snohomish Watershed, based on six key habitat characteristics. In general, they found that the independent drainages in WRIA 7 to be "degraded" based on the degree of loss of forest cover, increased area of impervious surfaces, degraded condition of stream channels, and modification of stream riparian areas. Based on these criteria, all of Mukilteo's drainages, including those in WRIA 8, appear to be moderately degraded or degraded.

3.0 BUFFER FUNCTION BAS

The City's classification system distinguishes between critical areas that are ecologically intact and performing functions characteristic of undisturbed ecosystems, and critical areas that are too small or have already been altered so that they do not perform many of these functions.

Within the area of shorelines jurisdiction, most wetlands are Category II or III, and streams are Type 2, 3, and 4. Most of the streams are confined within steep forested ravines. Therefore, this analysis focuses on buffers required in those wetland categories and stream types. City shorelines along the open waters of Puget Sound are separated from riparian areas by the presence of the Burlington Northern Santa Fe rail lines and are not considered in detail in this analysis.

3.1 Buffer Types

The City's CAO provides for minimum buffer widths around critical areas, including steep slopes, wetlands, streams, and shorelines. Many of the streams in Mukilteo are contained within steep wooded ravines and many of these ravines are protected as parks or green space (Figure 3). The slopes of many of these ravines, primarily along the lower stream reaches, are greater than 40 percent and so are regulated by the City as steep slopes. Construction setbacks extending 25 feet beyond the top of slope are required in areas of steep slopes. This extends the buffer to 25 feet beyond the top of the slope and so provides a larger buffer around the associated streams and wetlands than would otherwise be required.

3.2 Buffer Functions

3.2.1 General

Numerous studies and reviews of how vegetated buffers function to protect streams and wetlands have been conducted over the years. Although not all of these studies and reviews have undergone the peer review necessary to qualify as a "synthesis" of scientific information under the CTED guidelines (Chapter 365-195 WAC), they by-and-large adequately review and synthesize the larger body of peer-reviewed scientific investigations. For wetland buffers, McMillan (2000) and Ecology (Sheldon et al. 2003) provide recent reviews that are specifically focused on locally relevant literature and the requirements of the Washington Growth Management Act (GMA). For streams, Knutson and Naef (1997), Spence et al. (1996), the Forest Ecosystem Management Assessment Team (FEMAT 1993), and King County (2003) have reviewed the extensive literature regarding riparian functions provided by buffers along forested northwest salmonid streams. Desbonnet et al. (1994) reviewed riparian functions of estuaries, using primarily the considerable amount of field study along East Coast estuaries.

The functions that buffers provide are variable and dependent on their structure, including vegetation, soils, hydrology, slope, and aspect. In addition, similar to the critical areas they are intended to protect, buffers are dynamic and change both in response to natural successional processes and anthropogenic disturbances or influences. Thus the functions that buffers provide, such as removal of suspended sediments and other pollutants in stormwater runoff and wildlife habitat, also change over time. Furthermore, critical areas, especially streams and wetlands that have degraded or small existing buffers likely are limited in the functions they provide. For example, a narrow buffer (50 feet or less) composed of invasive plant species, such as Himalayan blackberry *(Rubus discolor)* and English holly *(Ilex aquifolium),* likely provides relatively low levels of wildlife habitat or water quality protection functions.

The buffer function curves of Spence et al. (1996) and FEMAT (1993) that relate buffer function to width of buffers are based on compilations and synthesis of data from multiple sources, mostly in forested watersheds of third- or larger ordered streams. Although streams in Mukilteo are primarily first and second order, the City considers these to represent BAS for these functions, as qualified in the following discussions. The data are typically related to the percentage of function provided the wetland or stream under pristine conditions, that is in relation to the level of function provided by an optimum mature forest buffer of infinite width. In setting buffer widths necessary to protect existing stream and wetland functions, it is recognized that some streams and wetlands in the City do not currently have buffers that provide functions equivalent to those extant under pristine conditions. In many areas, development has encroached upon and/or removed all or portions of the native vegetation around many critical areas, resulting in the degradation or reduction in the functions that these systems provide.

While literature syntheses are useful, they often fail to provide sufficient detail to allow the user to determine the conditions under which work in each cited reference was performed and therefore its relevance to specific situations and shoreline characteristics. There has been a tendency to extrapolate results from these studies (many of which have been completed on larger streams in forested watersheds) to streams of all sizes, or to estuarine and marine shorelines. Considering that the functions of streams and wetlands in highly urbanized areas likely do not provide the same level or even all functions comparable to those in largely forested watersheds, these data need to be evaluated carefully in the urban context.

This section is intended to be read in conjunction with those in Section 2, which discuss the role of buffers in the protection of critical area functions, as well as with the following sections. Buffers are one tool for maintaining or improving the functions discussed below, but, as discussed in Section 1.2, the reader should not assume that a buffer requirement is the only effective tool or that a buffer works in isolation from other tools that are being employed. In addition, buffer width may be meaningless when applied to areas in which the areas adjacent to critical areas have already been altered. For example, requiring a 100-foot buffer in an area that is already extensively developed with impervious surface would not restore functions that would be present in an undeveloped area.

3.2.2 Sediment Removal

Sediment removal by wetland and stream buffers are similar. Vegetated riparian areas trap sediment carried toward the stream overland by stormwater by slowing water velocities, promoting infiltration of surface flow, preventing gullying, and mechanically filtering and storing sediments (Lowrance et al. 1985). Desbonnet et al. (1994) have summarized a large number of studies regarding the sediment and pollutant removal effectiveness of riparian vegetation. Figure 4 and Table 6 summarize those data. Sheldon et al. (2003) have listed the factors affecting buffer performance and provided a table summarizing results of various studies. This table, reproduced here as Table 7, represents BAS regarding the effectiveness of vegetated buffers at removing sediments.

Fine sediments are widely recognized as adverse to functions of moderate to high gradient streams, such as those in streams that would normally have gravel or cobble beds or riffles, supporting salmonid spawning and rearing and a diverse benthic invertebrate fauna (Bjornn and Reiser 1991; Everest et al. 1987). Fine sediments can reduce intragravel flow and oxygen levels, reducing spawning success; eliminate microhabitat for juvenile salmonids and invertebrates; reduce primary and secondary productivity; and interfere with feeding and migration patterns.

Sediments can also cause adverse impacts on wetlands and influence the functions that they provide. In extreme cases where sediment loading and sedimentation rates are high, wetland vegetation can be buried. Although this may happen naturally as a result of episodic disturbance events (e.g., flooding and erosion events), sediment loading from urban areas can be a constant disturbance if there are continual point or nonpoint sources. Stormwater runoff from developed urban areas can be such a source.

Vegetation can also reduce the incidence of mass wasting events that increase sediment input to streams although Swanson et al. (1982) note that riparian vegetation may have little effect during large, deep-seated landslides. Likewise, the majority of surface stormwater runoff that enters streams and wetlands in the City enters through pipes or channels, thus bypassing the riparian zone and reducing the effectiveness of buffers at removing sediments and pollutants.

Riparian vegetation along tidal waters is likely to be as effective at trapping finer sediments being carried to the shoreline from upland sources as is riparian vegetation along streams. Marsh vegetation (below OHWM), in brackish marsh fringes along tidal stream mouths augment the sediment retention function of riparian vegetation above the OHWM. Levings and Jamieson (2001 have identified the importance of vegetated saltmarsh areas as a functioning part of their definition of marine riparian vegetation. Such marshes are largely absent in Mukilteo, and this function is not provided to any great extent.

The importance of the sediment retention function of riparian vegetation in limiting deposition of fines in streams is greatly reduced in the small streams and tidal waters along the shorelines of Mukilteo. Although fine sediments may be conveyed to Puget Sound by streams, deposition of these sediments is controlled by tidal circulation patterns and wave-driven transport and depositional processes. Along the shorelines of Mukilteo, there are no estuarine marshes that act as deposition areas.

Sediment carried overland through the riparian zone and into tidal waters will seldom (except perhaps by mass wasting) be of such a magnitude that water clarity is significantly altered. It is more likely the case that storm drains or streams deliver larger volumes of sediment-laden water from an entire shoreline drainage basin through a point source of flow onto the beach. Virtually all surface water flow to marine waters in the City is channelized through culverts through the railroad grade. In these cases, riparian conditions along the course of the stormwater flow from the uplands are more important in dictating water quality (upon entering the tidal water body) than is the riparian condition along the tidal area itself.

As indicated by Figure 4 and the studies summarized in Table 6, sediment removal is a non-linear function and effective removal is expected only under favorable buffer configurations or conditions that promote mechanical filtration. Favorable buffer configurations include well developed, relatively dense vegetation, relatively flat slopes, soils with permeabilities that promote infiltration, and diffuse flows. Conditions other than these, such as less dense vegetation, steeper slopes, relatively impermeable or slowly permeable soils, and concentrated flows are generally not conducive to sediment removal and reduce the effectiveness of the buffer to provide this function.

As shown on Figure 4 and in Table 6, a vegetated buffer of 50 feet is expected to be approximately 60 percent effective at suspended sediment removal while a buffer of 100 feet is expected to be about 70 percent effective. Tripling buffer width to 300 feet would gain an additional 10 percent effectiveness. It is generally assumed that there is a water quality protection function (e.g., sediment and toxicant removal) provided by riparian buffers. However, in many urban areas, this function may be short circuited by the existing development that surrounds the streams and wetlands within the City. As shown in the City's recently completed Comprehensive Surface Water Management Plan (Tetra Tech/KCM 2001), stormwater runoff is generally collected by man-made conveyance structures such as downspouts, gutters, catch basins, and culverts and routed around riparian areas directly to streams and wetlands. In such cases, the riparian buffers generally do not provide a water quality protection function because pollutant-laden stormwater runoff is conveyed directly to existing streams or wetlands.

3.2.3 Nitrogen and Phosphorus Removal

Buffers can be effective at controlling nutrient inputs to surface waters. Ecology (Sheldon et al. 2003) has listed the factors affecting buffer performance and provided a table summarizing results of various studies. This table, reproduced here as Table 8, represents BAS regarding the effectiveness of vegetated buffers at removing nutrients. Similar to sediment removal, nutrient removal by buffers is not a linear function of buffer width and effectiveness is widely variable. Those same biotic and abiotic factors that affect surface water flow and promote sediment removal (e.g., vegetation, slope, and permeable soils) also influence nutrient removal, especially for particulate forms. In addition, other abiotic and biotic characteristics that influence removal of dissolved nutrients include pH, dissolved oxygen, and redox potential of soils, pore water and shallow groundwater (i.e., chemistry) as well as the hydraulic residence time that determines physical uptake, microbial transformation (e.g., denitrification), and chemical transformation (e.g., complexation). In an earlier review of the literature, Castelle et al. (1992) presented the results of a number of studies that documented nutrient uptake within buffer strips. Buffer widths that were shown to be effective at reducing nutrient inputs ranged from 12.5 feet to over 300 feet. One study evaluated the utility of vegetated buffer in reducing soluble nutrient levels in runoff from logging operations and found that a 98-foot buffer reduced nutrient concentrations in the water to far below drinking water standards (Lynch et al. 1985). A brief discussion of red alder-dominated buffers as a source of Nitrogen will be added to the final.

Young et al. (1980) found that buffer strips of 118 feet were sufficient to reduce the concentration of nutrients to acceptable levels from feedlot runoff during summer storms. Shisler et al. (1987) found that wooded riparian buffers in the Maryland coastal region removed as much as 80 percent of phosphorus and 89 percent of nitrogen from agricultural runoff, most of it in the first 62 feet. Daniels and Gilliam (1996) showed that buffers of 18 to 67 feet width resulted in nitrogen reductions of 47 to 99 percent. Based on a review of 26 studies, Desbonnet et al. (1994) concluded that buffer width as small as 27 feet could reduce nitrogen as much as 60 percent, whereas buffer widths of up to 200 feet would be required to reduce nitrogen by 80 percent.

Nutrient sources in Mukilteo include runoff from lawns, parks, and golf courses. In addition, nutrients are present in urban stormwater runoff. Nutrients in runoff from residential lawns and urban runoff are likely typically conveyed by curb and gutter and catch basins to the City's stormwater drain system. These sources are discharged directly to streams, wetlands, or Puget Sound. Golf course runoff is conveyed to a system of stormwater ponds and constructed wetlands, where at least some nutrients (especially particulate fractions) are effectively removed. In many cases, non-point sources bypass buffers, and buffers do not provide a nutrient removal function. Where slopes are steeper than 5 percent and vegetation is composed of invasive species as is the case with some of the headwater areas of streams and disturbed wetlands, buffers likely provide limited nutrient removal as any flows that are present are concentrated in channels or vegetation does not filter suspended solids or have sufficient contact time to sequester nutrients. Thus, the nutrient removal function of buffers can be limited by the physical structure (e.g., slope and plant community composition) in many cases.

3.2.4 Bacteria, Pathogens, and Toxicants

Buffers can be effective at controlling non-point sources of fecal coliform bacteria, pathogen, and toxicant loadings into aquatic surface waters. Ecology (Sheldon et al. 2003) has listed the factors affecting buffer performance and provided a table summarizing results of various studies. This table, reproduced here as Table 9, represents BAS regarding the effectiveness of vegetated buffers at removing bacteria and pathogens. In a review of the literature, Castelle et al. (1992) presented the results of a fecal coliform reduction model for dairy waste management developed by Grismer (1981) and applied to the Tillamook Basin in northwestern Oregon. The model considered the effects of precipitation, season, method of waste storage and application, die-off of the bacteria in the storage containers, die-off of the bacteria on the land surface, infiltration of bacteria in the soil profile, soil characteristics, overland transport of bacteria through runoff, and buffer zones. Grismer's model suggested that a 98-foot "clean grass" strip would reduce the concentration of fecal coliform by 60 percent.

Young et al. (1980) found that a 106-foot grass buffer reduced microorganisms in surface water runoff to acceptable levels for primary contact recreational use (less than 1,000/100 ml).

Toxicants, such as pesticides and trace metals, also can be removed by buffers. Metals common in urban runoff in the region, such as lead, copper, and zinc (Galvin 1987; Galvin and Moore 1982), especially the particulate forms can be effectively removed by mechanical filtration. Particulate forms are physically adsorbed or attached to sediments and can be effectively removed in relatively short distances (e.g., 50 feet) provided favorable conditions exist (vegetation, slope, soils). Removal, transformation, or degradation of dissolved forms requires longer periods of time and contact with roots of plants, microbes, and dissolved organics that form complexes and make these substances less bioavailable.

Because the City does not have any significant agriculture, there are few septic systems in operation in the City's shoreline areas, and much of the urban stormwater runoff bypasses riparian buffers, the coliform removal function of buffers appears to be limited. Source tracking studies of *Escherichia coli (E. coli)* in Henderson Inlet (Thurston County 2002) found fecal coliform bacterial from humans, wild and domestic animals were common sources of *E. coli* to the inlet in both rural and urban watersheds. In an urban watershed (Woodland Creek) in that study, human, canine, birds, and dogs were predominant identified sources. Because there are few septic systems in Mukilteo, it appears likely that wild and domestic animals would contribute to potentially more fecal coliform bacteria than people to receiving waters in streams and wetlands. As with non-point sources of nutrients, fecal coliform bacteria found in stormwater runoff typically bypasses buffers, and buffers are unable to treat and remove them in such circumstances.

3.2.5 Shade and Temperature

Forested buffers adjacent to aquatic systems provide shade to the water surface, thereby helping to maintain lower water temperatures in summer (Beschta et al. 1987; Naiman et al. 1992). Overhanging canopy's, particularly of conifers can also lessen temperature decreases and freezing of surface waters in winter (Murphy and Meehan 1991), although this is seldom a problem in the Puget Sound lowlands.

High water temperature significantly affects the aquatic environment and associated species, including fish (Beschta et al. 1987). To determine whether riparian vegetation provides adequate shade to aquatic systems, several site-specific factors must be considered. These include composition of vegetation, stand height, stand density, latitude (which determines solar angle), topography, and the size and orientation of the aquatic system. These factors influence how much incident solar radiation reaches the forest canopy and the fraction that passes through to the water surface (Spence et al. 1996). Belt et al. (1992) reviewed numerous studies, and results indicated that removal of forest canopy within a buffer strip can reduce its effectiveness by diminishing shade and thereby increase stream temperatures. In well forested watersheds, mid-day summer water temperatures rise only 1 to 2°C (1 to 1.8°F) above year-round averages (Moring 1975, Beschta et al. 1987). Conversely, unbuffered streams in clearcut watersheds may experience temperature increases of 7 to 16°C (10 to 27°F), approaching temperatures that are lethal to salmon and other cold-water fish (Moring 1975; Ecology 1985; Beschta et al. 1987; Budd et al. 1987).

The generalized curves presented by FEMAT (1993) for forests in the Northwest suggest that cumulative effectiveness for shading approaches 100 percent at a distance of approximately 0.75 tree height from the stream channel (i.e., assuming a forest with an average tree height of 170 feet, a nearly 100 percent effective buffer for modification of water temperature in a larger stream is expected to be approximately 125 feet [Figure 5]). Smaller streams such as those in Mukilteo require shorter trees and narrower zones of riparian vegetation to completely shade them. In areas where partial or complete riparian clearing has exposed the water surface and caused increased stream temperatures, the rate of shade recovery depends on streamside vegetation types and stream size (Beschta et al. 1987).

Aspect and topography also influence stream temperature. Small streams, especially first and second order (Types 3, 4, and 5), in narrow drainages that are well confined by steep slopes may receive significant thermal protection from the topography and aspect. Such small streams also may be quickly (one to a few years) overtopped by brush and effectively shaded from solar radiation following removal of riparian vegetation by natural or human activities, while larger streams, which require tall trees for shade, require longer times (several years or decades). The majority of streams in Mukilteo (10 of 12) are oriented more or less east to west and located in steep-sided, forested drainages. It is likely that the topography and aspects of these drainages contribute significant thermal protection. In addition, the mature second-growth forest canopy contributes to moderation of temperature on these small mostly first and second order (Type 3, 4, and 5) streams.

Greater water depths and volumes of Mukilteo's marine waters mean only a small fraction of the water column is influenced by solar heating or shading. Tidal circulation and mixing of marine and fresh waters at the mouths of streams in nearshore areas further limits the influence of shading on water temperatures. The influence of riparian zone shading is further limited during low-tide periods when water volumes are at a minimum; under these conditions shading may only fall on exposed marshes and mudflats, not on the water surface.

In nearshore areas of Puget Sound, shading of the upper intertidal beach plays an important role in limiting the upward distribution of intertidal plants and animals (Foster et al. 1986). Typically the upper elevation at which intertidal biota can live is dictated by the degree of desiccation experienced during low tides. The rate of desiccation is clearly reduced on shorelines with a forested riparian zone; the influence of shading is dependent on the orientation of the shoreline with maximum shade on beaches with northern exposure. All of the natural, undeveloped shoreline areas in Mukilteo are west facing and little influenced by riparian vegetation because of the presence of the railroad fill.

Perhaps the most important function of shading in the nearshore area is in areas of surf smelt or sand lance spawning. These species spawn in the upper intertidal zone of sandy or sand and gravel beaches. In some areas of Puget Sound, surf smelt spawning occurs year round. Penttila (2001) reports that this spawning behavior is successful primarily on well shaded beaches. In otherwise suitable spawning areas that lack shade, spawning only occurs during the fall through spring months; egg survival from summer spawning is higher on shaded versus unshaded beaches. Mukilteo has three documented spawning areas. Spawning surveys were conducted in 2002 and 2003, but the data are not yet available (McCartney 2004). Almost all of the undeveloped beaches are west facing and are only minimally shaded during morning hours because of the existing railroad.

In summary, shading by riparian vegetation is an important moderator of water temperature in small to medium sized streams. Riparian vegetation also may provide thermal protection in wetlands with open water areas susceptible to warming by incoming solar radiation. However, the importance of this function is uncertain in the Puget Sound area where many wetlands receive groundwater, which is generally insolated from temperature effects by the ground surface. Shading is insignificant in moderating water temperature in tidally influenced, nearshore areas. In addition, because of the existing Burlington Northern Santa Fe railroad tracks, exposed intertidal beaches receive little thermal protection (shading) at low tide all along Mukilteo's shoreline areas.

3.2.6 Microclimate

Microclimate in riparian areas around wetlands and streams is of primary importance to the vegetation and wildlife (especially invertebrates and amphibians) that live in or pass through the riparian area. The effect of microclimate on stream temperatures is a direct result of shading as described in Section 3.2.5.

Important components of the microclimate in a forested area include solar radiation, soil temperature, soil moisture, air temperature, wind velocity, and air moisture or humidity (Chen 1991; Chen et al. 1992 [Figure 6]). Chen's (1991) data showed the following depth-of-edge effects: 100- to 295-foot penetration depths for solar radiation, soil temperature, and soil moisture; 590 to 787 feet for air temperature; and more than 787 feet for wind velocity and air moisture. These effects, however, are site-specific and vary with edge orientation and weather conditions (Chen 1991). Chen's studies also compare microclimate gradients among clearcut, edge, and interior forest and do not specifically examine riparian microclimate. Changes in microclimatic conditions within the riparian zone resulting from removal of adjacent vegetation, however, can influence a variety of ecological processes that may affect the long-term integrity of riparian ecosystems (Spence et al. 1996).

FEMAT (1993) presented generalized curves from Chen's work, relating protection of microclimatic variables relative to distance from stand edges into forests (Figure 6). These curves suggest that buffers would have to be extended an additional 1 to 2 SPT heights outside of the riparian zone needed for other functions (Figure 6) to maintain natural levels of soil moisture, solar radiation, and soil temperature within the riparian zone, and even larger buffers (up to 3 SPT heights; over 500 feet) to maintain natural air temperature, wind speeds, and humidity. The recommendations of FEMAT (1993) were based on studies in upland forests in the Cascade Mountains of the Pacific Northwest (Chen 1991). Their applicability to lowland riparian zones in urban areas is uncertain.

Brosofske et al. (1997) found riparian microclimatic gradients existed for air temperature, soil temperature, surface air temperature, and relative humidity. In contrast to the somewhat greater widths shown on Figure 6, Brosofske et al. showed that pre-harvest gradients approached upland forest interior values within 102 to 155 feet from the stream, although surface temperature and humidity gradients often extended farther (102 to 203 feet).

As noted in Section 3.2.5, riparian vegetation has little influence on the water temperatures in the nearshore tidal waters of Puget Sound. However, the tidal waters of Port Gardner and Puget Sound exert a significant effect on the microclimate (air temperatures, winds, and humidity) of the riparian areas and uplands of the Mukilteo area. In summary, establishment of minimum buffer widths to provide maximum microclimate functions, as determined in the above-referenced studies, would require buffers of widths that are simply not practicable in the UGA, and likely have no measurable effect on habitat for salmonids and minimal effect on other resources or buffer functions other than wildlife (see below).

3.2.7 In-Stream Habitat/Large Woody Debris

Numerous studies have shown that large woody debris (LWD) is an important component of fish habitat providing refuge from flow velocities, refuge from predators, and a substrate for production of prey (Swanson et al. 1976; Bisson et al. 1987; Naiman et al. 1992). Trees that fall into streams are critical for sediment retention and pool formation (Keller and Swanson 1979; Sedell et al. 1988), gradient modification (Bilby 1979), structural diversity (Ralph et al. 1994), nutrient production (Cummins 1974), and protective cover from predators. Large wood that enters stream channels originates from a variety of sources including tree mortality, windthrow, debris avalanches, deep-seated mass soil movements, undercutting of streambanks, and redistribution from upstream (Swanson and Lienkamper 1978).

Most assessments of buffer-width requirements for maintaining natural levels of LWD have considered only wood originating from tree mortality, windthrow, and bank undercutting (Spence et al. 1996). The potential for trees to enter a stream channel from local sources (rather than being carried downstream to a particular location) is mainly a function of slope and distance from the stream channel in relationship to tree height. As a result, the zone of influence for LWD recruitment is determined by the particular stand characteristics rather than an absolute distance from the stream channel or floodplain. Slope and prevailing wind direction are other factors that can affect the amount of LWD recruited to a stream (Spence et al. 1996). To maintain full recruitment potential of LWD to the stream channel, all trees within the zone of influence must be protected. FEMAT (1993) concluded that the probability of wood entering the active stream channel from greater than 1 SPT height is generally low. McDade et al. (1990) estimated that for old-growth conifer forests in Oregon, 50 percent of debris originates within 39 feet of the stream, 85 percent within 100 feet, and 100 percent within 165 to 182 feet. For mature forest, McDade et al. (1990) reported that these values are 33, 75, and 154 feet, respectively. They also showed that 90 percent of LWD in mature forests originated within 89 feet of the stream channel.

Working in conifer forested watersheds of southeast Alaska, Murphy et al. (1987) measured the percent of LWD that reached streams as a function of distance from the streambank and developed the data used to generate Figure 7. In their study area, a 50-foot buffer was sufficient to provide 89 percent of the maximum LWD and a 100-foot buffer provided virtually all of the expected LWD (Figure 7).

Cederholm (1994) reviewed the literature regarding recommendations of buffer widths for maintaining recruitment of LWD to streams and found that most authors recommended buffers of 100 to 200 feet to maintain this function. Most recent studies suggest buffers approaching 1 SPT height are sufficient to maintain 100 percent natural levels of recruitment of LWD (Spence et al. 1996).

It is important to note that the functional size (diameter and length) of LWD in a stream is dictated by channel width, and, therefore, the size of the channel can dictate the appropriateness of the buffer width for providing LWD (Bisson et al. 1987). In channels less than 16 feet wide, LWD as small as 20 to 30 cm (7.8 to 12 inches) in diameter can potentially form pools and trap gravel (Bisson et al. 1987; Beechie and Sibley 1997). By contrast, in channels 60 feet wide, pools do not form until debris of about 23.6 inches (60 cm) in diameter or larger enter the stream. It can therefore be inferred that smaller diameter LWD (7.8 to 16 inches) is functional on all of the smaller order streams found in Mukilteo.

In addition, the forested buffers on the Type 2 through 5 streams found in Mukilteo, do not require buffers of 100 feet to provide full LWD recruitment. Full LWD source potential can be provided with an abundance of functional LWD (trees larger than approximately 1 foot in diameter) within forested habitats immediately adjacent to the streams (e.g., within about 50 feet), assuming that there are active LWD recruitment processes (wind, mortality, normative flows, etc.). Mass wasting, which is relatively common on the steep ravines in the City as shown by the mapped landslides (to be added to final) and slide potential areas (Figure 8) may be a major mechanism and source of LWD recruitment.

The role of LWD in wetlands has not been the subject of detailed studies. However, it clearly functions in a number of different ways, including influence of vegetation structure, habitat for specific animals, and sediment retention. As LWD decays, it may become a nurse log for plants typically found in uplands. This is often clear in peatlands where upland trees and shrubs occur nowhere else. Snags and downed LWD provide food for invertebrates, which support insectivorous birds including woodpeckers. Woodpeckers may produce cavities in snags that are used by cavity-nesting birds and mammals. Logs provide basking habitat for turtles and may provide nesting, rearing, or overwinter habitat for small mammals and amphibians.

The presence of the rail line along the marine shoreline of Mukilteo eliminates most LWD recruitment directly to the nearshore and also prevents stranding of LWD. Rare exceptions are LWD recruitment that occurs from mass wasting (landslides) that cross the tracks and the occasional tree that may fall across the tracks and be pushed into the sound by maintenance crews. Log recruitment along the marine shorelines occurs primarily during larger storms when floating LWD from the Snohomish River is deposited along the upper shoreline where beaches exist, such as at the former State Park (J. Houghton, Pentec, personal observations).

LWD recruitment to streams and wetlands also has been altered by historical and ongoing land use practices. LWD recruitment potential has already been altered by encroachment of development, especially around wetlands. This development has reduced the number of trees within the riparian buffer capable of being recruited.

3.2.8 Leaf Litter/Insect Fall and Insect Production

Leaf litter and insect fall from riparian vegetation provide important indirect and direct energy sources to aquatic areas (Naiman et al. 1992). The nature and seasonality of organic litter fall varies greatly between coniferous and deciduous riparian habitats. The quality of energy sources also is variable. Coniferous forests provide relatively low quality needles and cones throughout much of the year, while deciduous forests provide more readily assimilated organic matter, primarily during the fall (Naiman 1992; Cummins et al. 1994). The relative contribution of litter fall by buffers of various widths is shown on Figure 5. The studies reviewed by FEMAT (1993) showed that most (about 90 percent) of the organic litter reaching West Coast streams originates from within about 0.5 tree heights from the channel. Thus, in areas with tree heights in the 80 to 100 feet range (typical of maturing second-growth trees along the small Type 2 through 5 streams in the City), full litter fall function would be provided by a buffer of 50 to 75 feet in width. Salmonid-bearing reaches of smaller streams in the City that lie in incised ravines, usually have reasonably intact streamside vegetation that likely provides near full function for leaf and insect fall.

Insects falling onto the stream surface provide a major source of food for juvenile salmonids (Healey 1991; Sandercock 1991). Because of their ability to fly and to be carried by winds, along with the affinity of some species for water surfaces at certain life history stages, insects can access water surfaces from varying distances. No references were found to relate insect abundance to buffer width. However, it is obvious that for certain types of insects, especially non-flying types, recruitment to the water surface will be greatest from vegetation immediately adjacent to or hanging over the water. For example, in a tidal estuary, Simenstad et al. (1997) found that juvenile salmonids preyed heavily on aphids that were abundant on adjacent marsh vegetation.

In marine environments, terrestrial invertebrates continue to provide a major prey base for juvenile salmonids despite increasing reliance on aquatic and marine crustaceans (Simenstad and Cordell 2000; Pentec 1992). A moist microclimate created by riparian vegetation can favor increased production of certain insect types (e.g., mosquitoes and flies; Diptera) often prominent in the diet of juvenile salmonids. Except for small wetlands associated with the mouths of streams and eelgrass beds, most of the shoreline of the City lacks vegetation and, therefore, lack significant riparian sources of leaf and insect fall.

Salmonid-bearing reaches of Mukilteo's streams have reasonably intact streamside vegetation that likely provides a high level of function for leaf and insect fall. Many of the insects consumed by fish in estuaries are produced in marsh vegetation below OHWM (Simenstad et al. 1997) but riparian scrub-shrub and forested areas are likely also important. A moist microclimate created by riparian vegetation can favor increased production of certain insect types (e.g., mosquitoes and flies; Diptera) often prominent in the diet of juvenile salmonids.

3.2.9 Wildlife Habitat

Riparian and wetland habitat zones are considered to be among the richest zones for aquatic organisms, mammals, and avian species (Clark 1977; Williams and Dodd 1979). Because wetland and riparian habitats exhibit an "edge effect," due to overlapping habitats, more niches are found within these areas than in any other habitat type. Eighty-six percent (359 out of 414) of the terrestrial vertebrate species in Western Washington use wetland and associated riparian habitats for portions of their life needs (Brown 1985). Buffer widths required to support wildlife vary tremendously depending on the species and their tolerance of human activity (Table 10). In general, buffers required to protect wildlife habitat functions of streams and wetlands are greater than those required for any other function except microclimate (see Table 6). It is not possible in the urban context of Mukilteo, to provide optimal habitat functions for wildlife (e.g., 1,640-foot widths for maintaining the greatest species richness of small mammals adjacent to wetlands in the Puget Sound lowlands as found by Richter and Azous [2001]). The current condition of the areas adjacent to critical areas in Mukilteo do not likely provide full wildlife habitat functions due to historical development patterns and existing land uses, which have fragmented the remaining habitat.

The literature on the effects of habitat fragmentation is varied and it is unclear how or whether this information is directly applicable to the highly urbanized landscape in Mukilteo. Human development and habitation have highly altered the structure and composition of habitat throughout western Washington since around the turn of the last century. Old growth forest has been eliminated and habitat complexity and diversity have been reduced in Mukilteo and other areas. The remaining second-growth forest habitat is highly fragmented, relatively homogeneous, and, in some cases, disturbed by human activities, such as dumping of yardwaste, and introduced, invasive plants and animals (e.g., Himalayan blackberry, purple loosestrife, reed canarygrass, and Norway rat). Where present these species degrade the habitat for native plants and animals by outcompeting them for limited resources and, in the case of the Norway rat, preying on native animals. Most of the remaining second-growth forest is confined to the relatively steep slopes surrounding the ravines that contain the many small streams in the City (Figure 2). These ravines support priority habitats identified by the WDFW, including riparian areas and wetlands. Forested habitats support a mix of native and non-native plants and animals commonly found throughout western Washington, including priority species listed by WDFW such as bald eagle and pileated woodpecker. There are seven known bald eagle nests in the forested ravines along the City's marine shoreline. A great blue heron colony has been reported and observed in Japanese Gulch (C. Ruedebusch, Pentec, personal communication). Other priority species identified by WDFW, particularly various waterfowl, are seasonal residents that use the shoreline areas for foraging and resting. Pacific salmon species, anadromous bull trout, and searun cutthroat trout also use the nearshore areas of Possession Sound, Puget Sound, and lower reaches of some of the streams.

3.2.9.1 Screening Noise, Light, Disturbance

Buffers protect wildlife habitat by limiting intrusion by humans and pets, and by screening out the noise, light, and motion of human activities. Buffers in urban settings discourage direct human disturbance to aquatic resources, such as by dumping debris, cutting vegetation, or trampling. All wildlife respond to human activities but the intensity and duration of the response varies with life-cycle stage and affected species. Animals may be most susceptible to disturbance during breeding or nesting periods. Disturbance at breeding and nesting time can lead to reduced populations caused by loss of eggs and/or young to predation or injury following abandonment by the parties. Repeated disturbance during feeding or resting can result in depletion of vital energy stores during flight or other avoidance reposes to humans (Josselyn et al. 1989).

Several authors have noted that increased buffer widths are needed to screen adjacent wetlands from noise and disturbance in high intensity use areas (summaries in Johnson and Ryba 1992; McMillan 2000). Buffers may provide a visual screen from high intensity land uses. However, there do not appear to be any data supporting the ability of vegetation to screen noise. Many areas along the shorelines in the City do not perform this screening function because of the existing development patterns. Noise from boat traffic in the sound, highway traffic on the Mukilteo Speedway, and trains is not reduced appreciably by buffers. In addition, is it unlikely that noise from commercial or other high intensity land uses is reduced significantly by buffers.

3.2.9.2 Nesting, Feeding, Breeding

The diversity of vegetation and landforms within wetland and riparian habitats provides the water and food requirements for many wildlife species. Surface water is used by many species that depend on free water during the drier and hotter seasons of the year. Surface water also facilitates feeding for wildlife (waterfowl, fish-eating birds, aquatic life history phases of amphibians, and some species of salamanders and reptiles). The vertical complexity and diverse vegetative composition of wetland and riparian systems provides many strata for foraging wildlife species (insectivorous and herbivorous). The Washington Department of Wildlife (WDW) (WDWHMD 1992) reports that 100-foot buffers are adequate for mallard nesting but that 300-foot to 600-foot buffers are needed for full protection of breeding by other waterfowl, herons, and western pond turtles. There are no significant waterfowl breeding habitat, or known populations of western pond turtles in the City of Mukilteo.

As noted above, many areas along the shorelines in Mukilteo do not perform this function because of the existing development and land use patterns.

3.2.9.3 Travel Corridors

Buffers may act as migration corridors between otherwise fragmented and isolated habitats. The use of buffers surrounding isolated critical areas as migration corridors or connections between other habitat likely depends at least in part on the characteristics of the buffer (e.g., vegetation structure and cover). Many wildlife species use riparian and associated wetland communities as natural travel corridors or dispersal corridors (Noss 1983 and 1987). Some species, such as deer or elk, may use these corridors to move between summer and winter ranges, and waterfowl and other avian species may use them during migration. Except for apparently small populations of deer, large ungulates or other animals with seasonal winter and summer range habitats are generally absent in Mukilteo. Amphibians and small mammals also appear to benefit from the maintenance of such connectivity. Habitat corridors become ever more important as urbanization degrades or eradicates habitats throughout a landscape.

Development along the marine shorelines of the City has altered wildlife travel corridors. However, there is some connectivity between the shoreline and all of the forested watersheds of the direct tributary streams to Puget Sound. These may be sufficient to maintain dispersal and migration corridors between populations allowing exchange of genetic material and preventing isolated populations, especially for smaller mammals, amphibians, and birds that are likely present. Habitat fragmentation caused by existing development, such as commercial, industrial, and residential development, likely already has negatively impacted populations of less mobile organisms. Because steep slopes may limit the ability to safely develop significant portions of these ravines, this connectivity is expected to be maintained and no further degradation of function is likely under either existing or proposed CAO scenarios.

3.2.9.4 Summary of Wildlife Habitat Functions

In general, it is clear that increased buffer widths provide proportionally greater wildlife functions (Keller et al. 1993; Milligan 1985; Wenger 1999) but in some cases those functions are only realized if the buffer corridor is linked by adequate corridors to larger forested areas. In summarizing buffer requirements for wildlife, the WDW (WDWHMD 1992) noted that 100-foot buffers provide certain functions, including some for amphibians and waterfowl nesting (e.g., mallard ducks, but in reduced numbers compared with larger buffers) and allowing for diverse songbird populations, but that they may eliminate mink and marten. They also reported that 50-foot buffers would support muskrat, and other small mammals, but would support a reduced diversity of birds.

The wooded ravines of many of the streams in Mukilteo provide water and food requirements for songbirds, amphibians, and small mammals. Forested ravines in Mukilteo often have a dense cover of understory vegetation or very steep slopes and function to limit intrusion in the streams and wetlands. The forested portions of the ravines are often much greater than 100 feet laterally from the streams and, therefore, provide a moderate to high level of buffer function. Most of these areas are protected as either parks or open space because of the stream and/or steep slope buffer requirements. However, other areas along the shorelines in Mukilteo do not perform this screening function because of the existing development patterns.

3.2.10 Shoreline Stabilization

In addition to providing important microhabitat for sheltering small fish, roots and vegetative cover physically bind streambank sediments while vegetation and woody debris along and above streambanks reduce flow velocities, thus reducing scour. Reduced water velocity in vegetated floodways also promotes sediment deposition and bank building. Logic would suggest that this function can only be served by vegetation that is at or very near the streambank; FEMAT (1993) concluded that the role of root structures in maintaining streambanks is very limited beyond a distance of about 50 feet from the stream (Figure 5). Logic would also dictate that lesser vegetated widths would be needed to provide full function for bank stabilization in progressively smaller streams that generate lesser erosive forces.

The great majority of marine shorelines in the City are protected by riprap along the railroad or concrete bulkheads. In these areas, the role of vegetation in bank stabilization has been largely replaced by riprap and bulkheads.

In nearshore areas, vegetation is generally only minimally effective in resisting the forces of tides and storm waves that occur at high tide. However, vegetation can help reduce the rate of slope toe erosion to a potentially acceptable level (Myers 1993). In addition, in areas with steep eroding bluffs, maintaining native vegetation is usually the best tool for keeping the bluff intact and minimizing erosion (Broadhurst 1998). Vegetation can be valuable in sustaining slope stability even in cases of mass soil movement due to the complex root network formed by trees and shrubs (Manashe 1993). Potentially unstable slopes may be held together by the roots, and the resistance of the soil to slipping, sliding, and washing away is increased. In addition, plants absorb water and slow its velocity, metering the rate of discharge (Manashe 1993). Bioengineering is an example of using vegetation to decrease erosion and increase shoreline stability (Zelo and Shipman 2000). Riparian vegetation including saltmarsh plants can help stabilize geologically young shoreline features such as gravel or sand spits for a time, but such features are maintained more by shoreline processes (e.g., gravel recruitment and storm erosion) than by vegetative stabilization (Schwartz et al. 1991).

The majority of the marine shoreline of the City is occupied by the rail line that effectively controls shoreline erosion. Occasional landslides that originate in the bluffs south of the rail line may cross the tracks and thus provide a source of sediment to the beaches north or west of the tracks. In summary, shoreline vegetation can play a role in shoreline stabilization in streams and in tidal areas, but its importance in the marine nearshore area in Mukilteo is minimal. Because the full function of vegetation at streambank stabilization is achieved with relatively small buffer widths, this function is not considered critical for establishing appropriate buffer widths for streams in Mukilteo.

3.2.11 Buffer Width Effectiveness and Quality of Buffer

Several factors are identified in the studies cited above as influencing the effectiveness of buffers at providing each of the buffer functions discussed. Primary among them is streambank slope, which is key to the filtration and infiltration functions that attenuate sediment, nutrients, and toxic materials in the course of surface water movement through buffers (Dillaha et al. 1989). Flatter slopes reduce flow velocities and provide more opportunities for trapping, binding, biological degradation, or infiltration of various contaminants. As discussed elsewhere, buffers can only provide water quality protection function where there are sources of non-point pollution entering the buffer as sheet flow. In cases where stormwater conveyance structures rills or channels bypass stormwater directly through the buffer to a wetland or stream, the potential water quality improvement function is also bypassed.

The nature of buffer vegetation is also critically important in providing several of the buffer functions. Grasses and herbaceous vegetation may be more effective at some water quality functions because of their greater influence on the flow of water over the ground, as compared to forested buffers. However, forested buffers are clearly essential to providing shade for larger streams and LWD for all streams. Well developed forested buffers occur along most of the length of the small independent drainages to Puget Sound within Mukilteo. With one partial exception (Japanese Gulch), streams also flow through steep ravines along much of their length. Steep slope setbacks (25 feet from the top or toe of the slope) effectively increase the stream buffers in these areas beyond the required minimum in these areas (see Figure 2). For example on Big Gulch (Type 2) X (calc using GIS) percent of the stream length is within steep slope areas. The effect of the steep slope buffer requirement is to increase the stream buffer to X (calc using GIS) feet. Flatter areas exist at the heads of many streams in the City. However, except for some wetland areas, this flatter terrain is less commonly forested. Increasing the minimum buffer widths in areas that have no forested cover would provide only a limited increase in function in part because existing development has already encroached upon the streams leaving little natural vegetation or buffers that are degraded by invasive species and/or yardwaste dumping. In some of these areas enhancement of the existing buffer can provide a greater increase in function (especially the food web/wildlife habitat and water quality protection functions in areas dominated by Himalayan blackberry and English ivy) than increasing the buffer width. Although areas of invasive species have not been mapped or inventoried in detail, they are pervasive throughout the City.

Similar circumstances exist around many wetlands in flatter areas, such as Harbour Pointe (more GIS figures and/or tables showing area protected by existing versus proposed buffers will be added to the final). Many of these wetlands have small forested buffers and are surrounded by residential and/or commercial development. In some cases, the buffers have been degraded by illegal dumping of yardwaste and by invasive species. As with streams, enhancing the existing buffers likely would have more positive effect on protection of wetland functions than increasing the buffer width to include developed areas that effectively provide no function because of existing buildings and other impervious surfaces.

4.0 EFFECTIVENESS OF EXISTING VERSUS PROPOSED BUFFER AMENDMENTS

4.1 Buffers in the Urban Context

Urban areas including the City of Mukilteo contain or border streams, wetlands, and marine shoreline that provide valuable aquatic habitat. Some of these areas are in relatively unspoiled condition, but most have been altered by urban use and development.

A principal purpose of critical area regulations is to protect (i.e., not degrade) the functions and values that these areas provide locally and to the larger ecosystem. Best available science includes taking into consideration the various tools employed in City development regulations (which include both the SMP and CAO) in establishing buffer width and determining the effectiveness of buffers (see Section 3.0 above).

A related purpose, for jurisdictions such as Mukilteo that use these regulations to implement comprehensive plan and shoreline policies directed toward restoring natural systems, is to provide incentives for restoring and enhancing these riparian and estuarine functions for water quality, fish and wildlife, open space and recreation, neighborhood quality, economic vitality, and other objectives. Best available science considers the key functions and restorative opportunities and locations (or types of locations) that should be encouraged, consistent with applicable land use and watershed planning. This includes consideration of the degree to which buffer widths are likely to be effective in encouraging restoration or enhancement of important riparian and estuarine functions in existing developed or degraded areas.

Critical areas regulations applying to urban areas, therefore, may be directed both to preserving existing high quality natural environments, and to encouraging the restoration of functions in areas that have been degraded but could be improved to provide valuable functions, particularly from a larger ecosystem or watershed perspective.

Buffer width is only one tool that is used in preserving or improving riparian and estuarine functions, and it may be much less important in protecting these functions than other tools, as noted in Sections 1.2. Without detracting from the importance of preserving and enhancing habitat in urban areas, it is important to understand the urban context for using buffers in light of the BAS literature. For example, in urban and urbanizing areas such as the City of Mukilteo, construction is likely to be the major source of sediment that could enter aquatic habitats (Wenger 1999). Construction sites in Mukilteo are required to use best management practices (BMPs) to limit transport of sediment off site and sites are actively inspected to ensure that they are effective.

In reviewing the following analysis, it is important to keep in mind that much of the literature cited in Section 3.0 has been developed in studies in rural and forested areas where it is a societal objective to preserve existing natural populations of fish and wildlife along with existing habitats and habitat-forming processes. The City of Mukilteo exists in a landscape that has been highly altered over many decades. The ecological landscape surrounding the City is itself highly altered by other urban centers, and transportation corridors. Areas within the Mukilteo UGA cannot be expected to provide natural habitat for many species that require large areas of contiguous forest habitat. Likewise it is important to recognize that the majority of the streamside buffer data are related to streams that are much larger than the small streams inside the UGA. The small streams in the Mukilteo UGA have little present contribution to listed salmonids. As noted, most of the research regarding buffer width effectiveness has been conducted in rural, forested areas. There is less available scientific literature that evaluates effectiveness of buffers for different functions in urban environments. In considering the scientific literature in addressing buffer widths for the City of Mukilteo, the following differences between the study areas and the City environment are important factors:

- Existing shoreline areas are often highly developed or otherwise altered and do not provide a number of the functions of such areas in rural areas. BAS does not support setting aside large buffers that do not provide a meaningful functional benefit.

- Functions primarily performed by buffers in rural areas, such as management of stormwater for erosion and flooding, are regulated by additional means in the city (e.g., detention, retention and other stormwater facilities). The City may use these other tools to maintain or enhance shoreline functions in a manner that is consistent with best available science and the City's authority to balance the full range of objectives under the GMA and SMA.

As a result of these factors, the scientific literature developed in rural areas must be reviewed and applied carefully when developing buffers in urban areas.

In setting its buffers around wetlands and along streams and marine shorelines of an urbanized area, the City of Mukilteo must also strike a balance among other critical policy objectives. These include:

- The mandate of the GMA to focus future population density and employment opportunities within the City's UGA; and

- The SMA preference for a variety of uses in the shoreline area.

Field studies of the effectiveness of vegetated buffers often seek to develop a relationship between buffer width and the level of performance, on a scale of 0 to 100 percent, of various ecological functions. The 100 percent performance of buffer function is an optimum, usually based on data from pristine ecosystems. For example, most of the work on riparian function along streams in the Northwest has been conducted in upper watershed areas and in mature forests. In most cases where data of this sort have been plotted (Figures 4 through 7), it is evident that a large proportion of the buffer function (i.e., over

50 percent) is achieved with a relatively moderate buffer width (30 to 50 feet) and increasingly broader buffers are required to add to that function. For example, from Figure 4 and Table 6, we see that a 15-foot buffer is effective at removing about 50 percent of sediment, and 66- to 98-foot buffer widths are required to remove about 70 percent of sediment. Tripling buffer width to 300 feet would achieve only an additional 10 percent effectiveness at removal of sediment and pollutants.

The state, in providing guidance regarding recommended buffer widths, has recognized that it may not be possible or desirable to achieve 100 percent of each buffer function. As noted, the state's recommended buffer width (300 feet) achieves approximately 80 percent of the function of sediment removal and recognizes some reduction in functionality for large wildlife species (McMillan 2000). Similarly, local governments establishing buffer requirements based on BAS as mandated by GMA, recognize that buffers that are reasonable to impose and enforce in urban growth areas may not provide 100 percent of each buffer function as determined from available scientific studies. In the following discussion, the effectiveness of Mukilteo's buffer widths is compared with the effectiveness of a hypothetical buffer providing 100 percent of each function discussed. As noted, even the state's recommended guidelines are not 100 percent effective for a number of functions.

For example, Mukilteo's buffer width of 100 feet for Type 2 streams outside of steep slope areas and for Category I wetlands, will achieve approximately 70 percent or more of most functions except microclimate moderation (see Figures 4 through 7). Given the moderating effect of Puget Sound and the heating effect of urban areas, it is unclear what effect a smaller buffer may translate to on the ground. From Figure 4 and Table 6 it can be seen that tripling the width of the buffers for these areas (to 300 feet) would achieve an additional 10 percent of full function for sediment and pollutant removal and that approximately 656 feet (200 m) would be required to achieve 90 percent of full buffer function for sediment and pollutant removal and to provide excellent, rather than good, general wildlife value. The City of Mukilteo Planning Department has evaluated the loss to the buildable land base, the scarcity of locations for water dependent uses, and other factors that would result from increasing the buffer from 100 to 300 feet, and has weighed it against the benefit of an increase of 10 percent in buffer effectiveness. Mukilteo staff have also considered the other tools that it is using to address sediment control and other issues.

Emphasis in setting buffer widths in urban areas should be placed on protecting existing sensitive aquatic habitats and on providing the functions most important in the urban environment. For example, very large buffer widths have been shown to be necessary to provide maximum function for wildlife (Table 10). In the highly urbanized area within Mukilteo, it appears likely that wildlife diversity has already been adversely affected by habitat fragmentation and high road density as well as high levels of residential, commercial, and industrial land uses. Many species, especially mammals with large home range requirements (e.g., bear, cougars, and bobcat) or species intolerant of human activity and development (e.g., grizzly bear and wolverine) no longer are present or may be incapable of being sustained regardless of buffer width. The City, therefore, has not set its buffer widths at a level that in a pristine environment would provide maximum function for such species. Proposed buffer widths represent a compromise for sustaining populations of animals known or likely to be found in the City and balancing other GMA goals, such as concentrating development within the UGA.

In the following section, habitat types present in the Mukilteo UGA are described and the most important buffer functions listed. An assessment is then made of how well the existing and proposed buffer widths will provide for those functions.

4.2 Wetland and Wetland Buffer Functions within the City of Mukilteo

4.2.1 General

Wetlands often exist between aquatic and terrestrial ecosystems and, in those instances, are influenced by both. Wetlands types are identified, in part, by the kinds of plants that grow in them, by the degree of surface flooding, or by their soil saturation caused by a high water table. Functions of wetlands have been defined as the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of wetland ecosystems. Some processes have importance to society because they have an economic value, such as water storage, which reduces the impacts of flooding downstream. Other processes may include aesthetic and water quality value or value as fish and wildlife habitat. Not all wetland sites provide all values discussed above, due to site-specific characteristics and their locations within the landscape. For example, a small wetland composed of scrub-shrub vegetation may provide specific habitat requirements for various wildlife, but not serve a hydrologic function (flood retention or water quality) because of its hydrologic characteristics or topographic position.

Development in urban areas may radically alter the physical, chemical, and biological conditions within and near wetlands. However, substantial knowledge has developed about how wetlands operate, what is necessary for their protection and to sustain their functioning, and how to restore some of the functions when they have been impaired or lost. The width of a buffer considered appropriate to protect a wetland from degradation is related to the wetland functions being protected and the buffer functions being provided. Factors such as the location of wetland resources within the landscape and its associated environment (urban versus rural) also dictate the appropriateness of buffer widths. For example, substantial wetland buffers have been shown to be necessary to protect wildlife function in areas adjacent to wetlands (Table 10). These substantial buffers were recommended to protect habitat features for a wide variety of wildlife species found in rural environments. Many wildlife species that may be present and desirable in a rural setting may not be present or desirable in an urban setting, thus, these substantial buffers are not considered appropriate for urban lands. Within the urban setting, it is more appropriate to require narrower minimum buffers that provide habitat for smaller wildlife that are compatible with urban and residential neighborhoods and that provide visual separation between wetland and developed environments. Certainly buffers should at least block glare and human movement from sensitive wildlife associated with the wetland. Wetland types and their associated functions must also be considered when establishing buffer requirements, as a one-size-fits-all approach is not always appropriate.

Because of the degree of development in the City, most of the wetlands have been identified, delineated, and classified. The majority of Category I and II wetland habitats within the City of Mukilteo are on the south end of the City. They are depressional wetlands near the headwaters of smaller streams and may provide groundwater recharge to associated streams. Groundwater recharge and potential contributions to stream flow are related to the elevation of the wetland relative to groundwater, hydraulic head pressure, and the physical characteristics of the wetlands substrate (hydraulic conductivity), which effect the transmissivity of surface water to groundwater. It is thought by some that headwater wetlands contribute to base flow support in streams by gradually releasing stored water during the dry season. Adamus et al. (1991) in their review of the literature, found that this assumption is inaccurate in most cases because discharge from wetlands during the dry season is very small if it exists at all. Depending on their geomorphology and storage capacity, one of the primary functions of these depressional flow-through, headwater wetlands is likely peak flow reduction and erosion control in the streams receiving stormwater runoff. Another function of these hydrogeomorphic wetland types is likely pollutant removal and retention, especially those wetlands in the golf course area. Pollutant removal effectiveness depends on many factors including the hydraulic residence time, substrate and water chemistry characteristics (e.g., pH, dissolved oxygen, temperature, amount of light, and organic matter), timing and duration of flooding, and vegetation structure. Because wetlands likely receive considerable amounts of pollutants in urban runoff, one of the primary functions in Mukilteo may be protection of downstream receiving waters including their outlet streams, Possession Sound, and Puget Sound.

In addition to the depressional flow-through hydrogeomorphic types, there are some slope type wetlands and some riverine flow-through wetlands associated with the steep ravines and streams. There appears to be a limited number of these wetlands types within the City limits. However, it is possible these have not been fully identified because they are not easily accessible in the steep forested ravines.

Of the known wetlands in the City, there are two Category I wetlands; both have development on all sides set back by the 50-foot buffer required under the existing code. There are 17 Category II wetlands that all have buildings or roads around all sides set back by the currently required 25-foot buffer. Most of the platted lots in the vicinity of the wetlands have been built or have been issued building permits under the existing MMC. Because most of the established wetland buffers in the City are surrounded by existing development, increases in buffer width requirements would have no impact on protection of buffer or wetland functions. Enhancement of the existing buffers is the only reasonable alternative for improving buffer function at most of the wetlands in the City. Potential enhancements would include removal of invasive species and planting native trees, shrubs, and herbs. These enhancements would most benefit the biological support and water quality protection functions of buffers. Such enhancements also would be expected to improve the biological support and water quality protection (assuming increased organic matter input and retention) functions of associated wetlands. Other functions likely would remain comparable to existing conditions.

4.2.2 Effectiveness of Existing Versus Proposed Wetland Buffers

BAS indicates that standard wetland buffer widths required by Mukilteo's CAO likely provide from 70 percent (water quality) to near 100 percent (shade, bank stabilization, leaf and insect fall) effectiveness for key buffer functions for Category I and II wetlands (see Figures 4 through 7 and Tables 6 through 10). Mukilteo's buffer requirements also provide about 50 to 60 percent effectiveness for the water quality function for Category III and IV wetlands. Wildlife functions of small mammals, songbirds, and some amphibians are well protected by a 100-foot buffer. It appears that Mukilteo's buffer widths are appropriate and reflect BAS for wetland buffer minima within the UGA.

In identifying and applying BAS for the review of Mukilteo's existing standard buffer widths, the appropriateness of wetland buffer widths should reflect the differences between the rural and urban environments discussed above. The various buffer studies and buffer width recommendations identified in this report (Section 3) were based on a variety of studies, most of which were conducted in different environmental settings (e.g., rural or natural). In applying BAS to Mukilteo's existing buffers, therefore, it is important to apply BAS that is appropriate for Mukilteo's environmental setting.

As previously stated, wetland buffers provide a variety of functions for wetland systems. For evaluating Mukilteo's existing buffer standards, three key buffer functions were identified and were evaluated based on Mukilteo's urban environmental setting:

- Water Quality
  - Sediment reduction;
  - Nutrient removal; and
  - Fecal coliform and pollutant removal.

- Wildlife Habitat
  - Cover, foraging, and nesting for birds, small mammals, and amphibians; travel corridor for small mammals.

- Shade, Leaf Litter and Insect Fall

As outlined in Table 4, Mukilteo's proposed buffer widths for Category I, II, III, and IV wetlands are 100, 75, 50, and 25 feet, respectively. These standard buffer widths for all category wetlands represent the minimal buffer requirement. Category I wetlands include large, higher-quality, and/or regionally rare wetlands of irreplaceable ecological functions. Given the synthesis of BAS in Section 3, the 100-foot standard buffer identified for Category I wetlands would provide at least 70 percent effectiveness in removing sediments and pollutants (Table 6), assuming favorable slope, vegetation, and soils. Slope has been identified as one of the primary site-specific factors affecting buffer efficiency at removing sediment and pollutants (Dillaha et al. 1989, McMillan 2000). Riparian areas around the City's Category I wetlands are relatively flat. Thus, the 100-foot buffer for Category I wetlands will likely provide greater efficiency than that indicated in Table 6 for sediment and pollutant removal. The two Category I wetlands within the City limits are associated with small Type 4 streams that do not support fish. Buffers of 100 feet function as high quality wildlife habitat for small mammals, amphibians, and avian species (WDWHMD 1992), and appear to be appropriate for an urban setting. The proposed buffer is the same as the existing buffer for Category I wetlands. So, the level of protection would remain the same. In addition, the buffers around these wetlands are constrained by existing development.

The 75-foot buffer associated with Category II wetlands would also have 70 percent or greater effectiveness in sediment and pollutant removal; however, it would have somewhat reduced wildlife habitat value (Table 6). Most of the wetlands that are near the headwaters of Big Gulch Creek and Picnic Point Stream (Type 2 streams with significant anadromous fish habitat value) are Category II wetlands. It is likely, although uncertain given the lack of water quality data, that removal of 70 percent or more of sediment and other pollutants that may be present in urban runoff is adequate to protect salmonid rearing habitat. Proposed buffers would be expected to provide 70 percent shade and 92 percent leaf and insect litter fall functions protecting salmonids and other aquatic biota according to Figures 5 and 7. Because the wetlands receive stormwater runoff from pipes, the actual pollutant removal effectiveness is likely lower than predicted. The proposed buffers are 50 percent larger than those now existing for this category and would provide greater water quality protection, wildlife habitat, and shade functions than now exist. As such they would appear to be protective of existing wetland functions.

A minimum 50-foot buffer is mandated for Category III wetlands, which include wetlands not meeting criteria for Category I or II wetlands, but which are of greater quality than Category IV wetlands. This buffer would be expected remove 60 percent or more of any sediment and pollutants in diffuse flows moving across them. They would provide minimal wildlife habitat function that is commensurate with the reduced wildlife habitat value provided by the wetlands themselves (recall that Category III wetlands are generally small in size, do not include riparian wetlands, and do not contain multiple wetland types; Table 2). The 25-foot buffer associated with Category IV wetlands (those wetlands that are hydrologically isolated, have an area less than or equal to 1 acre, contain one vegetation class, and are 80 percent or greater dominated by invasive species) would be expected to provide about 50 percent or more sediment and pollutant removal effectiveness but provide poor to minimal habitat value for wildlife. Given the small size, lack of vegetative diversity, isolation, and presence of invasive species, such wetlands have comparatively low habitat value for wildlife.

Although the 50-foot and 25-foot buffer requirements for Category III and IV wetlands provide less than 70 percent effectiveness in removing sediment and pollutants, and have poor to minimal value for wildlife, these wetland types are of lower quality and likely do not require buffers of greater than 50 or 25 feet to protect their associated functions. Neither of these wetland types contains an open water component, is associated with riparian and stream habitats, or is associated with sensitive species or habitats. Additionally, they are less than 1 acre in size, and exhibit low vegetation structural and species diversity. Thus, the reduced potential function compared to that provided by wider buffers is of little significance beyond the wetland itself, i.e., any reduced function in Category IV wetlands will not significantly affect any other wildlife or fish habitat. In addition, the proposed buffers are 50 percent larger than the existing buffers now required for Category III wetlands and would be expected to be proportionally more protective of existing wetland functions.

4.3 Stream and Stream Buffer Function within the City of Mukilteo

4.3.1 General

There are all or portions of 13 watersheds within the City of Mukilteo and the UGA. All the streams flow directly into Puget Sound. Using both the existing and the proposed stream classification system, there are no Type 1 streams within the City limits. The City of Mukilteo Steams and Wetlands map (Figure 1) shows two Type 2, three Type 3, five Type 4, and one Type 5 streams (proposed classification system) at their confluences with Puget Sound. Two streams are extensively culverted at their mouths (Brewery Creek and Chennault Creek; see Figure 1). Type 2 streams are defined as having greater than 20-foot bankfull width and include Japanese Gulch Creek and Big Gulch Creek. Picnic Point Creek and Lunds Gulch Creek are south of the City limits but within the City's municipal UGA. The upper portions of these streams are smaller Type 4 or intermittent Type 5 systems. The lone exception is Big Gulch Creek, which is a Type 3 stream at the headwaters within the Harbour Pointe Boulevard culverts.

Type 2 streams in the City may support populations of chum and coho salmon or cutthroat trout, but salmon habitat is generally limited to lower reaches of these streams. Upper reaches of these waters are inaccessible because of barriers to fish passage and likely support only resident cutthroat trout. Many of these reaches are degraded by stormwater runoff from developed areas as shown in maps contained in the Comprehensive Surface Water Management Plan (Tetra Tech/KCM 2001). Stormwater runoff and development in the watersheds of these streams has contributed to a flashy hydraulic characteristics, lower base flows, greater erosion and sedimentation, and degradation of aquatic habitat quality. Conveyance of stormwater runoff is one of the primary functions of all streams. The flashy hydrology of these streams likely reduces the quality of instream habitat for aquatic invertebrates, other aquatic biota, and amphibians.

Type 4 and 5 streams do not support either anadromous or resident salmonids. Similar to Type 2 streams, one of the primary functions is conveyance of stormwater runoff. Although stormwater runoff has degraded habitat quality, these systems still provide some level of functions but at lower levels than those in less disturbed drainages. The various buffer studies and buffer width recommendations identified within this report (Section 3) were based on a variety of studies that were conducted in different environmental settings.

4.3.2 Effectiveness of Existing Versus Proposed Stream Buffers

It is somewhat difficult to compare existing buffers with the proposed buffers because of the different structure of existing compared to proposed stream classification system. Under the existing MMC, Type 2 stream require a 75-foot buffer and Type 3 streams require a 25-foot buffer. Under the proposed regulations, Type 3 streams under the existing code are equivalent to Type 3, 4, or 5 under the proposed code. As shown in Table 5, Mukilteo's proposed buffer widths for Type 2, 3, 4, and 5 streams are 100, 75, 50, and 25 feet, respectively.

Under the proposed regulations buffers would be increased 33 to 50 percent for all stream classes compared to the existing regulations. The 100-foot buffers required by the City for Type 2 waters would be expected to provide 70 percent or greater of the optimal function for water quality. Based on the studies referenced in Section 3.0, buffers 100 feet wide provide 75 to 99 percent of the optimal functions for bank stabilization, LWD recruitment and shade and about 97 percent effectiveness for leaf and insect fall (Figure 5).

In reality, because of their very small size and more or less complete canopy cover, Type 2 streams in Mukilteo buffers would likely provide closer to 100 percent of the shade and leaf and insect fall. Because of the small size of Mukilteo's streams, buffer widths of 50 feet or greater required for Type 2, 3, and 4 streams will be essentially 100 percent effective at providing streambank stabilization and LWD recruitment (Figures 5 and 7). Production of detritus and insect fall has been shown to largely occur from vegetation within 100 feet of the stream (Figure 5). However, for streams the size of even the Type 2 streams in Mukilteo, the existing riparian vegetation of second growth mixed deciduous/coniferous forest forms a near continuous canopy over the streams. Thus, the existing buffers provide nearly 100 percent of litter and insect fall that would be expected to occur. Smaller buffers required for Type 3 and 4 streams also provide a continuous canopy over the streams and would provide a very high percentage of the maximum insect and litter fall. As conduits for stormwater runoff, which appears to be one of the primary functions of all streams in Mukilteo, the proposed buffers appear to be protective of existing degraded functions.

Existing wildlife habitat functions, such as foraging, breeding, and resting habitat for small mammals, songbirds, and some amphibians would receive greater protection from the larger proposed buffers for each stream type than provided by the existing buffers. In many cases, the effective buffer would be larger than 100 feet on those reaches of all streams, regardless of type, because the streams flow in steep ravines that are mostly in parks or green space (Figure 3) and that require a setback to be placed at the top of the slope buffer (Figure 2).

Independent, Type 3, 4, and 5 streams in the City of Mukilteo support relatively simple communities of aquatic biota, are very small, and have minimal (Type 3) to no (Type 4 and 5) resident fish resources. As mentioned previously, one of the primary functions of these streams is conveyance of urban stormwater runoff. This function does not require buffers. The importance of and need for buffers in these streams differ from the importance of and need for larger buffers in similar order streams that are tributary to larger anadromous fish streams such as Japanese Gulch, Big Gulch, Picnic Point Creek, and Lunds Gulch.

A 100-foot buffer is expected to be at least 70 percent effective, and a 50-foot buffer at least 60 percent effective at removing sediment and pollutants (Tables 6 and 7 and Figure 4). Given the lower gradient of slopes in the upper reaches of these streams, it is expected that actual effectiveness will be on the higher end of the pollutant removal range cited in the literature. Sediment or nutrients entering these streams are carried directly to Puget Sound without passing through streams with ESA-listed species. The lower reaches of each of the Type 2 streams are buffered by steep and wooded ravines that have effective buffers that are wider than the minimum 100-foot buffer required by the proposed regulations. Existing regulations provide the same level of buffer and protection in these areas through application of the existing steep slope buffer requirement. Additional quantification of area protected by buffers will be provided in the Final Draft.

Several of the steep ravines, such as Japanese Gulch, Olympic View Ravine, Big Gulch, and Picnic Point Creek are up to 1,600 feet wide at the widest point and average about 550 feet in width.

As previously stated, river and stream buffers provide a variety functions in rural or natural areas. For evaluating Mukilteo's existing buffer standards, three key buffer functions were identified and were evaluated based on Mukilteo's urban environmental setting:

- In-stream Habitat and other Associated Functions:
  - Bank stability;
  - LWD recruitment and organic input; and
  - Detritus production.

- Water Quality:
  - Sediment and pollutant removal;
  - Nutrient removal;
  - Fecal coliform removal; and
  - Temperature (shade).

- Wildlife Habitat:
  - Cover, foraging, and nesting for birds, small mammals and amphibians; travel corridor for small mammals.

As outlined in Table 5, Mukilteo's minimum standard buffer widths for Type 2, 3, 4, and 5 streams are 100, 75, 50, and 25 feet, respectively. These standard buffer widths for all stream types represent the minimal buffer requirement, and the CAO contains provisions for increasing buffer widths to protect stream and river shorelines that are sensitive to disturbance or are associated with sensitive habitats (e.g., rookeries) or fish and wildlife species.

Water Quality. As noted above, one of the most important factors influencing buffer effectiveness for the water quality functions is slope (McMillan 2000). Also noted above is the fact that the upper reaches of the small independent drainages in Mukilteo lie in relatively flat terrain. Based on Figure 5, a 100-foot buffer is expected to be 70 percent effective, and a 50-foot buffer 60 percent effective at removing sediment and pollutants. Given the lower slopes in the upper reaches of these streams, it is expected that actual effectiveness will be somewhat higher. Sediment or nutrients entering these streams are carried directly to Possession Sound without passing through streams with ESA-listed species. Erosion and sedimentation are common problems in the steep ravines. The naturally high erosion and sedimentation rates associated with the glacial deposits in these ravines has been increased by use of these systems for conveyances for stormwater runoff. There are no available water quality data, but nutrients are not known to be a problem in any of these streams. Sediments from the Japanese Gulch and Brewery Creek drainages constitute the only significant source of sediment seaward of the rail line. As such, these sediments are critical to the maintenance of their respective stream mouth deltas, which have been shown to provide the highest quality salmon habitat along this reach of shoreline in Port Gardner. The lower reaches of each of these Port Gardner drainages (both Type 2 streams) are buffered by the steep and wooded ravines through which they flow. These ravines, which are protected by the CAO as critical areas, provide effective buffers that are much wider than the minimum 100-foot buffer.

Wildlife Habitat. Because of the small size of Mukilteo's streams and because buffer width is applied to both sides of each stream, the width of wildlife habitat along each stream is essentially double the buffer width. For example, a 100-foot buffer would result in a 200-foot corridor. Although no comprehensive surveys of wildlife use have been conducted in the City, wildlife habitat along the City's streams within the UGA is generally limited to small mammals, birds, and amphibians. Columbian black-tailed deer are present in some areas. In addition, there reportedly have been sightings of at least one mountain lion. This animal appears to use the BNSF tracks as a corridor to access the otherwise fragmented remaining forested habitats that provide sufficient cover and prey (McCartney 2003). Given the large home ranges of these animals, it seems likely that this animal's territory includes other habitats outside the City. The 100-foot buffers (200-foot corridors) are expected to provide wildlife migration corridors and connections to the forested habitats that provide nesting, feeding, and rearing needs capable of sustaining populations of those species now found in these areas. The 75-, 50-, and 25-foot buffers (150-, 100-, and 50-foot corridors) along the Type 3, 4 and 5 streams will maintain the existing wildlife habitat functions. Proposed regulations would not reduce the connectivity, increase habitat fragmentation, or reduce the quality of existing habitat. On the contrary, they would be more protective of remaining habitat than existing regulations.

4.4 Summary of the Effectiveness of Existing Versus Proposed Buffer Requirements

Establishment of buffers around wetlands, streams, steep slopes, and marine shorelines of an urbanized area such as the City of Mukilteo must strike a balance between the following realities:

- The mandates of the GMA and ESA for use of "best available science";
- The mandate of GMA to focus future population density and commercial activities within the City's UGA; and
- The reality that the City exists within an altered landscape that cannot be expected to provide optimal habitat for all species.

Emphasis in setting buffer widths in urban areas should be placed on protecting existing important and/or sensitive aquatic habitats and providing the functions most important in the urban environment. In applying BAS to Mukilteo's buffers, it is therefore, it is important to consider the nature of the wetlands and streams present.

The proposed changes to City of Mukilteo CAO in all cases, either maintain or increase the existing buffer widths. These changes thus provide increased protection of existing critical area functions. Wetlands and streams with the highest resource value and function receive the greatest level of buffer protection. Also, there are provisions to increase the standard buffers to protect particularly sensitive aquatic habitats.

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TABLES

Table 1 - Proposed Buffers and their Anticipated Effectiveness at Providing Selected Key Functions Based on the BAS

Wetlands

Category and Buffer[1]	SH, LF, LWD	WQ[2]	HAB[3]
I – 100 feet	75, 97, 100	70	Some small mammals, songbirds, and amphibians.
II – 75 feet	70, 92, 100	70	Some small mammals, songbirds, and amphibians.
III – 50 feet	40, 70, 87	60	Minimal general wildlife habitat.
IV – 25 feet	25, 36, 82	52	Minimal general wildlife habitat.

Streams

Category and Buffer[1]	SH, LF, LWD	WQ[2]	HAB[3]
2 – 100 feet	75, 97, 100	70	Some small mammals, songbirds, and amphibians.
3 – 75 feet	70, 92, 100	70	Some small mammals, songbirds, and amphibians.
4 – 50 feet	40, 70, 87	60	Minimal general wildlife habitat.
5 – 25 feet	25, 36, 82	52	Minimal general wildlife habitat.

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[1] Minimum standard buffer outside of steep slope areas. Larger buffers (25 feet beyond top of slope) are provided for streams and wetlands within steep slope areas.

[2] Sediment and pollutant removal function dependent on diffuse or sheetflow, shallow slope, vegetation density, and soil characteristics. Where stormwater runoff is routed directly to streams and wetlands, this function may not be provided to a large extent.

[3] Wildlife habitat function varies depending on species.

SH – shade
LF – leaf fall
LWD – large woody debris recruitment
WQ – sediment and pollutant removal (water quality)
HAB – wildlife habitat

Table 2 - City of Mukilteo Wetland Categories (Proposed CAO Section 17.52B.090)

Category I	• Documented habitat recognized by federal and state agencies for threatened and endangered plant, animal, or fish species; or • Documented high quality Natural Heritage wetland sites, or high quality native wetland communities, that qualify as Natural Heritage wetland sites; or • Wetlands with irreplaceable ecological functions; or • Documented wetlands of local significance.
Category II	• Documented habitat for sensitive plant, animal, or fish species recognized by federal or state agencies; or • Wetlands with documented priority habitat or species recognized by State agencies or; • Wetlands with rare wetland communities, significant habitat value based on diversity and size, and wetlands contiguous with salmonid fish-bearing waters including streams where flow is intermittent; or • Wetlands with significant habitat functions that may not be adequately replicated through creation or restoration. • Wetlands with significant habitat value greater than or equal to 22 points (freshwater wetlands).
Category III	• Wetlands that do not contain features outlined in Category I, II, or IV wetlands.
Category IV	• Less than 1 acre and hydrologically isolated, comprised of one vegetated class that is dominated (>80% areal cover) by soft rush, hardhack, or cattail. • Wetlands less than 2 acres and hydrologically isolated, with one vegetated class and 90% of areal cover is predominately of exotic species. • Wetlands that are ponds excavated from uplands and are smaller than 1 acre without a surface water connection to streams, lakes, rivers, or other wetlands throughout the year, and have less than 1/10 acre of vegetation.

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Source: Ecology (1993). Note that this document is currently being revised and it is likely that the City will adopt any subsequent revisions for the purposes of classifying and evaluating wetland functions.

Table 3 - City of Mukilteo Stream Type Definitions (Proposed CAO Section 17.52C.070)

Type 1	• Streams inventoried as shorelines of the state under the City's SMP. *(There are no Type 1 streams located within the City limits of Mukilteo).*
Type 2	• All waters not classified as Type 1, with 20 feet or more between each bank's OHWM and a gradient of less than 4%.
Type 3	• Stream segments having a defined channel or 2 feet or greater within the bankfull width in Western Washington, and which have a moderate to slight use and are moderately important from a water quality standpoint for domestic use, public recreation, and fish and wildlife habitat.
Type 4	• All segments of natural waters within the bankfull width of defined channels that are perennial nonfish habitat streams. Perennial streams are waters that do not go dry any time of a year of normal rainfall. However, for the purpose of water typing, Type 4 Waters include the intermittent dry portions of the perennial channel below the uppermost point of perennial flow.
Type 5	• All segments of natural waters within the bankfull width of the defined channels that are not Type 1, 2, 3, or 4 Waters. These are seasonal, non-fish habitat streams in which surface flow is not present for at least some portion of the year and are not located downstream from any stream reach that is a Type 4 Water. Type 5 Waters must be physically connected by an above-ground channel stream to Type 1, 2, 3, or 4 Waters.

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Source: Excerpted from WAC 222-16-031 Interim Stream Types

Table 4 - Minimum Existing and Proposed Buffers for Wetlands in the City of Mukilteo (Proposed CAO Section 17.52B.100)

Wetlands	Existing Buffer in Feet[(a)]	Proposed Buffer in Feet[(b)]
Category I	100	100
Category II	50	75
Category III	25	50
Category IV	NA	25

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[(a)] The existing ordinance is three tiered (Type I, II, and III wetlands).

[(b)] These are the minimum proposed buffers with enhancement based on staff's 2002 recommendations and may change following review of this document.

Table 5 - Minimum Existing and Proposed Buffers for Streams in the City of Mukilteo (Proposed CAO Section 17.52C.070)

Streams (Class/Type)	Existing Buffer in Feet [(a)]	Proposed Riparian Buffer Width in Feet [(b)]	
		Outside of Designated Steep Slope Areas	Within Designated Steep Slope Areas
I	100	N/A	There are no Class I or Type I streams in the City.
II	75	100	25 from the top of slope
III	25	75	25 from the top of slope
IV	N/A	50	25 from the top of slope
V	N/A	25, unless culverted	25 from edge of stream or buffer

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[(a)] The existing ordinance is three tiered (Class I, II, and III Streams).

[(b)] Proposed stream classifications use DNR Interim Stream Types (WAC 222-16-031); Measured horizontally on each side of the stream from the ordinary high water mark.

Table 6 - Summary of Sediment and Pollutant Removal Effectiveness and Wildlife Habitat Value Based on Buffer Width (Desbonnet et al. 1994)

Buffer Width in Feet (m)	Pollutant Removal Effectiveness	Wildlife Habitat Value
16 (5)	Approximately 50 percent or greater sediment and pollutant removal	Poor habitat value; useful for temporary activities of wildlife
32 (10)	Approximately 60 percent or greater sediment and pollutant removal	Minimally protects stream habitat; poor wetland habitat; useful for temporary activities of wildlife
49 (15)	Greater than 60 percent sediment and pollutant removal	Minimal general wildlife and avian habitat value
66 (20)	Greater than 70 percent sediment and pollutant removal	May have use as a wildlife travel corridor for some species as well as some avian habitat value
98 (30)	Approximately 70 percent or greater sediment and pollutant removal	May have use as a wildlife travel corridor for some species as well as minimal to fair wildlife habitat
164 (50)	Approximately 75 percent or greater sediment and pollutant removal	Minimal to fair general wildlife habitat value
246 (75)	Approximately 80 percent or greater sediment and pollutant removal	Fair to good general wildlife and avian habitat value
328 (100)	Approximately 80 percent or greater sediment and pollutant removal	Good general wildlife habitat value; may protect significant wildlife habitat
656 (200)	Approximately 90 percent or greater sediment and pollutant removal	Excellent general wildlife value; likely to support a diverse community
1,968 (600)	Approximately 99 percent or greater sediment and pollutant removal	Excellent general wildlife value; supports a diverse community; protection of significant species

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Table 7 - Summary of Studies on Sediment Control Provided by Buffers of Various Widths (Sheldon et al. 2003)

Author(s)	Date	Buffer Width in Feet (m)	Comments
Broderson	1973	200 (61)	Effective sediment control "even on steep slopes" as cited by Castelle and Johnson (2000)
Desbonnet et al.	1994	6.6 to 82 (2 to 25)	60 percent removal in 6.6 feet (2 m); 80 percent removal required 80 feet (25 m)
Desbonnet et al.	1994	16 to 49 (5 to 15)	On grassy buffers on slopes with less than 5 percent slope, removed all but the finest particles. Cited by McMillan (2000)
Ghaffarzadeh et al.	1992	16 to 49 (5 to 15)	Found 85 percent removal in 30-foot (9.1 m) buffers as cited by Castelle and Johnson (2000)
Horner and Mar	1982	200 (61)	80 percent of sediments. As cited by Castelle and Johnson (2000)
Lynch, Corbett, and Mussallem	1985	98 (30)	75 to 80 percent removal of sediment from logging activities into wetlands. As cited by Castelle and Johnson (2000)
Norman	1996	9.8 (3): sands 49.9 (15.2): silts 400 (122): clays	Distances required for effective removal of progressively smaller particle sizes
Wong and McCuen	1982	100 to 200 (30.5 to 61)	90 percent at 100 feet (30 m), need 200 feet (61 m) to obtain 95 percent removal effectiveness. Cited by Castelle et al. (1994)
Young	1980	80 (24.4)	92 percent removal rate from feedlot through vegetated buffer strip. Cited by Casteel et al. (1994)

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Table 8 - Summary of Studies on Nutrient Removal Provided by Buffers of Various Widths (Sheldon et al. 2003)

Author(s)	Date	Width in Feet (m)	Comments
Daniels and Gilliam	1996	20 - 66 (6 - 20)	47 to 99% removal of nitrogen, cited by McMillan (2000)
Desbonnet et al.	1994	30 (9): 60% removal 197 (60) 80% removal	Small buffers could have effective removal rates for nitrogen; much larger buffers are necessary for a significant increase in effectiveness
Desbonnet et al.	1994	Averages: 39 (12): 60% 279 (85); 80%	When all the findings from the literature synthesis were averaged, the average removal efficiencies were non-linear: larger buffers were needed for increases in effectiveness
Dillaha	1993	15 (4.6): 70% 30 (9.1): 84%	Percent removal of suspended solids and their associated nutrients with vegetated filter strips. As cited in Todd (2000)
Dillaha	1993	15 (4.6): 61% 30 (9.1): 79%	Removal of phosphorus with vegetated filter strips. As cited by Todd (2000)
Dillaha	1993	15 (4.6): 54% 30 (9.1): 73%	Removal of nitrogen with vegetated filter strips. As cited by Todd (2000)
Doyle, Stanton and Wolf	1977	12.5 t (3.8) forested 13.1 (4) grass	Reduced nitrogen, phosphorus, and potassium levels. Cited by Castelle and Johnson (2000), McMillan (2000)
Edwards et al.	1983	98 (30)	50% removal rate of phosphorus. As cited by McMillan (2000)
Lowrance et al.	1992	23 (7)	Forested buffer zones were effective at removing nitrate through plant uptake and microbial denitrification
Lynch, Corbett and Mussallem	1995	98 (30)	Forested buffers reduced soluble nutrient levels from logging activities to “appropriate” levels. Cited by Castelle and Johnson (2000)
Patty et al.	1997	20 to 66 (6 to 20)	47 – 99% removal of nitrogen, as cited by McMillan (2000)
Peterjohn and Correll	1984	164 (50)	Forested buffer strips provided “dramatic reductions in nutrient loads from crops: as cited by Belt and O’Laughlin (1994)
Shisler, Jordan, and Wargo	1987	62 (19)	Forested riparian buffers effectively removed up to 80% and 89% of phosphorus and nitrogen, respectively. Cited by Castelle and Johnson (2000)
Thomson et al.	1978	39 to 118 (12 to 36)	Found a range of removal effectiveness of 44 to 70%. As cited by McMillan (2000)

Table 8 - Summary of Studies on Nutrient Removal Provided by Buffers of Various Widths (Sheldon et al. 2003)

Author(s)	Date	Width in Feet (m)	Comments
Vanderholm and Dickey	1978	> 853 (260)	Removal of 80% of nutrients, solids, and BOD from feedlot runoff with shallow (<0.5%) buffer slopes. Cited in Castelle et al. (1998)
Young et al.	1980	69 (21): 67% removal 89 (27): 88% removal	Removal of phosphorus, as cited by McMillan (2000)
Xu, Gillam and Daniels	1992	33 (10)	Significant reductions in nitrate through a mixed herbaceous and forested buffer strip. As cited by Castelle and Johnson (2000)

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Table 9 - Summary of Studies on Nutrient Removal Provided by Buffers of Various Widths (Sheldon et al. 2003)

Author(s)	Date	Width in Feet (m)	Comments
Doyle, Stanon and Wolf	1977	12.5 (3.8) forested buffers 13.1 (4) grass buffers	Reduction in fecal coliform bacteria levels as cited by Castelle and Johnson (2000)
Grismer	1981	98 (30) grass filter strip	Removal of 60% of fecal coliform bacteria as cited by McMillan (2000)
Young et al.	1980	115 (35) grass buffer	Reduced microorganisms to acceptable levels. Cited by McMillan (2000)

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Table 10 - Summary of Studies on Wildlife Habitat Provided by Buffers (Sheldon et al. 2003)

Author(s)	Date	Width in Feet (m)	Comments
Allen	1982	328 to 590 (100 to 180)	Mink use: generally concentrated within 330 feet (100 m) of water but will use upland habitats up to 590 feet (180 m) distant
Burke and Gibbons	1995	240 (73): 90% 902 (275): 100%	Buffer to encompass % nesting and hibernation of turtles in North Carolina
Castelle et al.	1992	197 to 295 (60 to 90): Western Washington	Range for all species they noted
Castelle et al.	1992	263 (80) avg. - 590 (180)	Wood duck nesting locations from wetland edge (non-Washington data)
Castelle et al.	1992	328 (100): Western Washington	Distance of beaver use of upland habitats from water edge
Chase et al.	1995	98 (30) or more	100 feet (30 m) would be "adequate"; buffers larger than 100 feet needed to meet habitat needs, including breeding for birds and some mammals
Cross	1985	220 (67)	Forested "leave-strips" for small mammal richness adjacent to streams in SW Oregon
Desbonnet et al.	1994	49 to 98 (15 to 30): low intensity 98 to 328 (30 to 100): high intensity	Variable buffer widths using adjacent land uses as decision-making criteria
Fischer et al.	2000	98 (30) minimum	Literature review; majority of literature cited recommends buffer widths of 330 feet (100 m) for reptiles, amphibians, birds, and mammals
Foster et al.	1984	98 (30): 68% of nests 312 (95): 95% of nests	Waterfowl breeding use of wetlands in the Columbia Basin greatest in smaller (<1 acre [0.4 ha]) wetlands; 68% of waterfowl nests within 100 feet (30 m) of wetland edge; to encompass 95% of waterfowl nests would require 310 feet (95 m) of buffer
Groffman et al.	1991	197 to 328 (60 to 100)	For most wildlife needs
Groffman et al.	1991	328 (100)	Neotropical migratory bird species
Howard and Allen	1989	197 (60)	For most wildlife needs
McMillan	2000	98 to 328 (30 to 100)	Based on a synthesis of literature

Table 10 - Summary of Studies on Wildlife Habitat Provided by Buffers (Sheldon et al. 2003)

Author(s)	Date	Width in Feet (m)	Comments
Milligan	1985	49 (15)	Bird species diversity strongly correlated with the percentage of the wetland boundary buffered by at least 50 feet (15 m) of tree and shrub vegetation
Norman	1996	164 (50)	To protect wetland functions; more buffer may be required for “sensitive wildlife species”
Ostergaard	2001	3,280 (1,000)	Forested habitat surrounding stormwater ponds, related to native amphibian richness
Richter	1996	3,280 (1,000	Literature review and synthesis
Richter and Azous	2001b	1,680 (512)	Distance from wetland edge necessary to include all bird richness in Puget Sound lowland wetlands
Richter and Azous	2001c	1,640 (500): 60%	Highest small-mammal richness when 60% of first 1,640 feet (500 m) of buffer was forest habitat
Semlitsch	1998	1,969 (600)	Salamanders
Semlitsch	1998	228 to 411 (69.6 to 125.3) 539 (164.3) for 95% of all species	Six species of adult salamanders and two species of juveniles; mean distance from wetland edge was 228 feet (juveniles) – 411 feet (adults). To incorporate 95% of all species, buffer mean would have to be 539 feet
Short and Cooper	1985	164 to 328 (50 to 100)	164 feet (50 m) for foraging
Temple and Cary	1988	>656 (>200): 70% success 328 to 656 (100 to 200) 58% success <328 (<100): 18% success	Nesting success rates for interior-dwelling forest birds related to distance into the interior of a forest from the forest edge

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FIGURES

City of Mukilteo Existing Streams and Wetlands

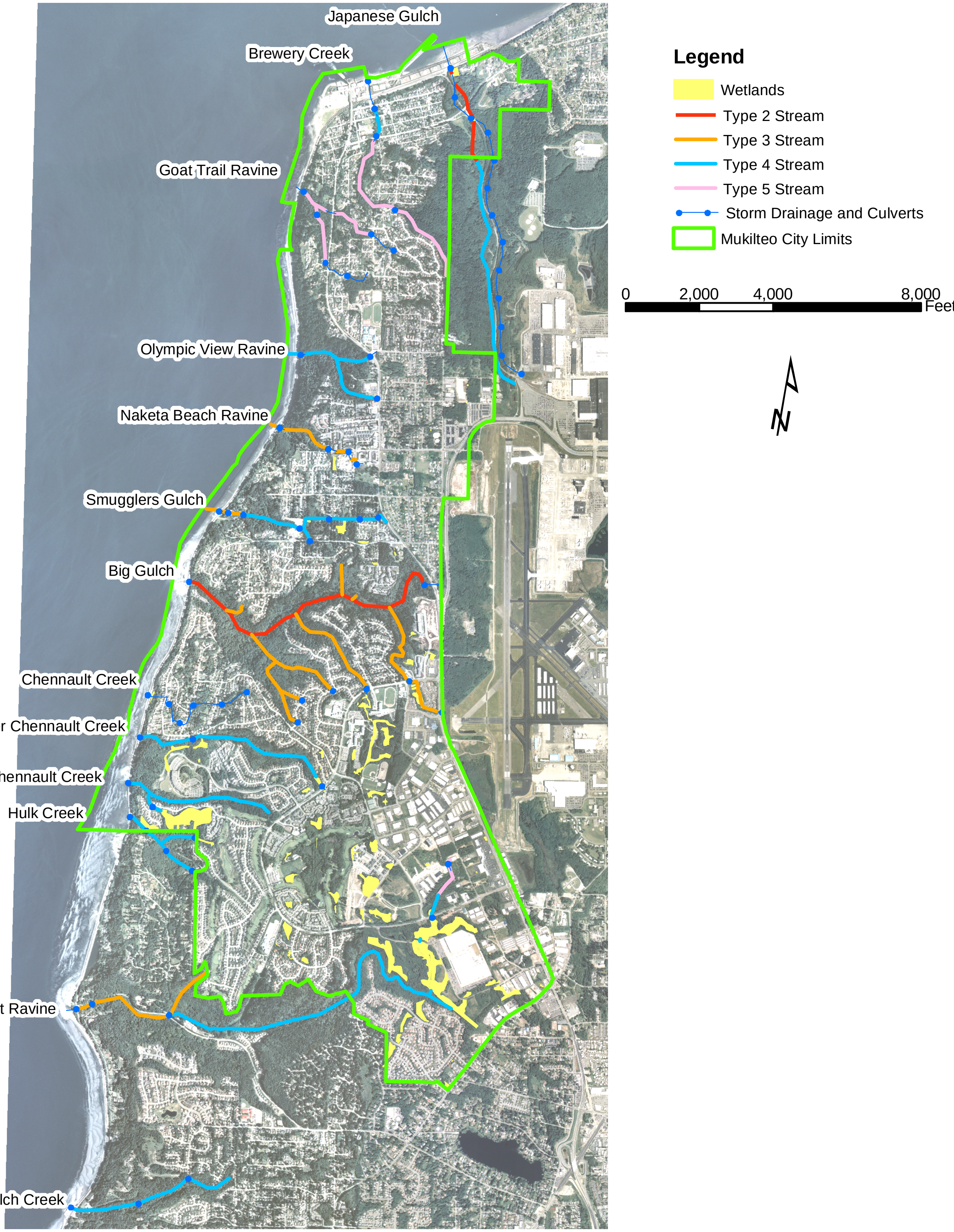

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Figure 1

Figure 2 – Effective Buffer Width for Streams within Steep Ravines

TO BE ADDED TO FINAL DRAFT OF REPORT

City of Mukilteo Parks and Open Space

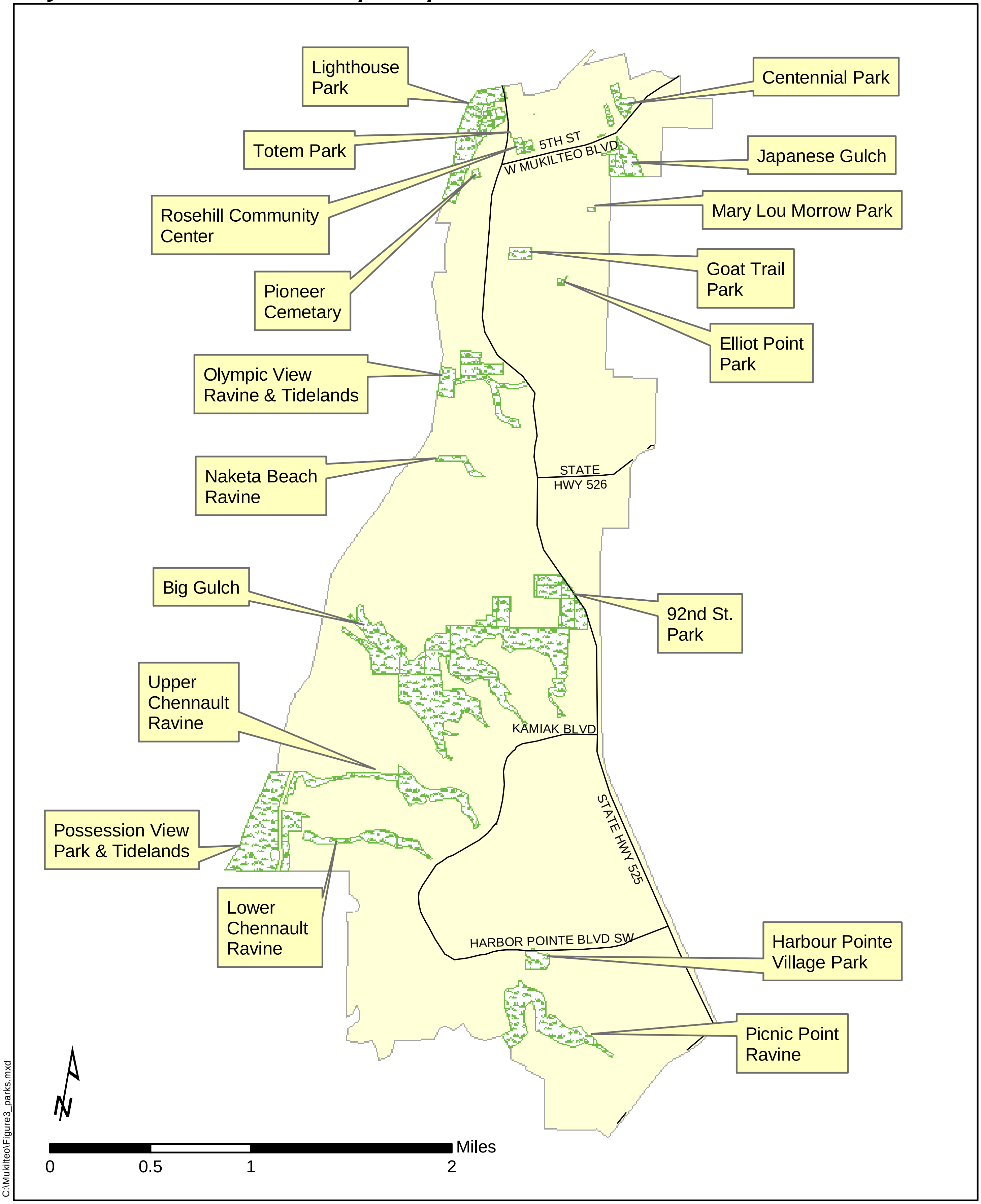

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Figure 3

Figure 4 Percent Effectiveness of Riparian Buffers at Removing Sediment and Pollutants (adapted from Desbonnet et al. 1994).

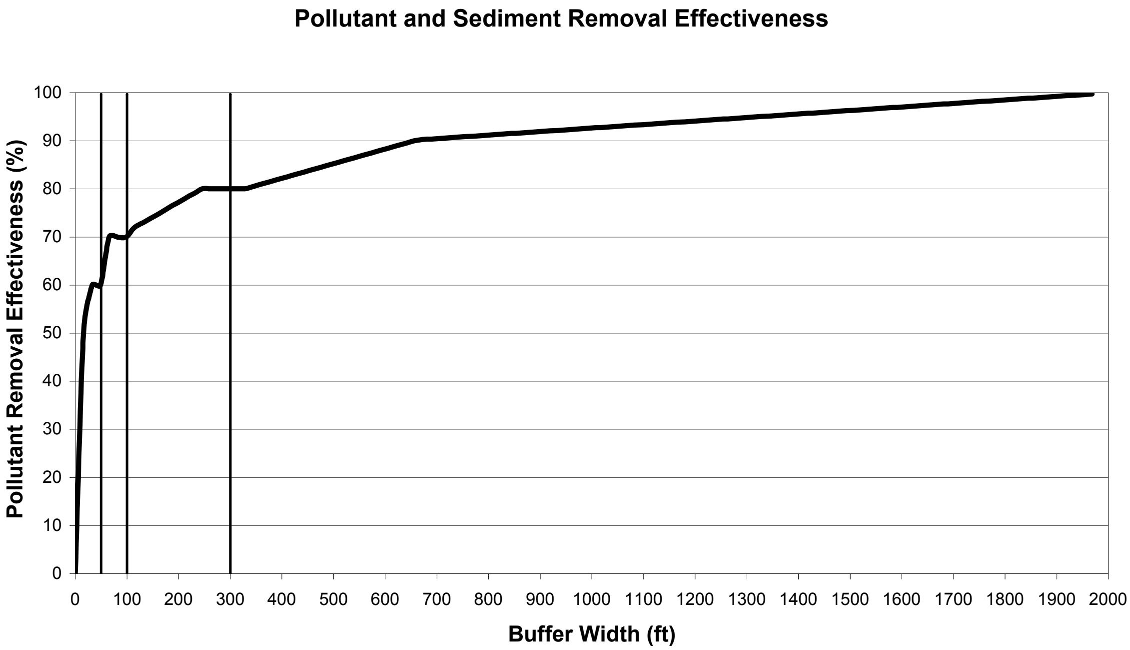


Figure 5 Percent Effectiveness of Several Riparian Functions in Relation to Buffer Width (adapted from FEMAT 1993).

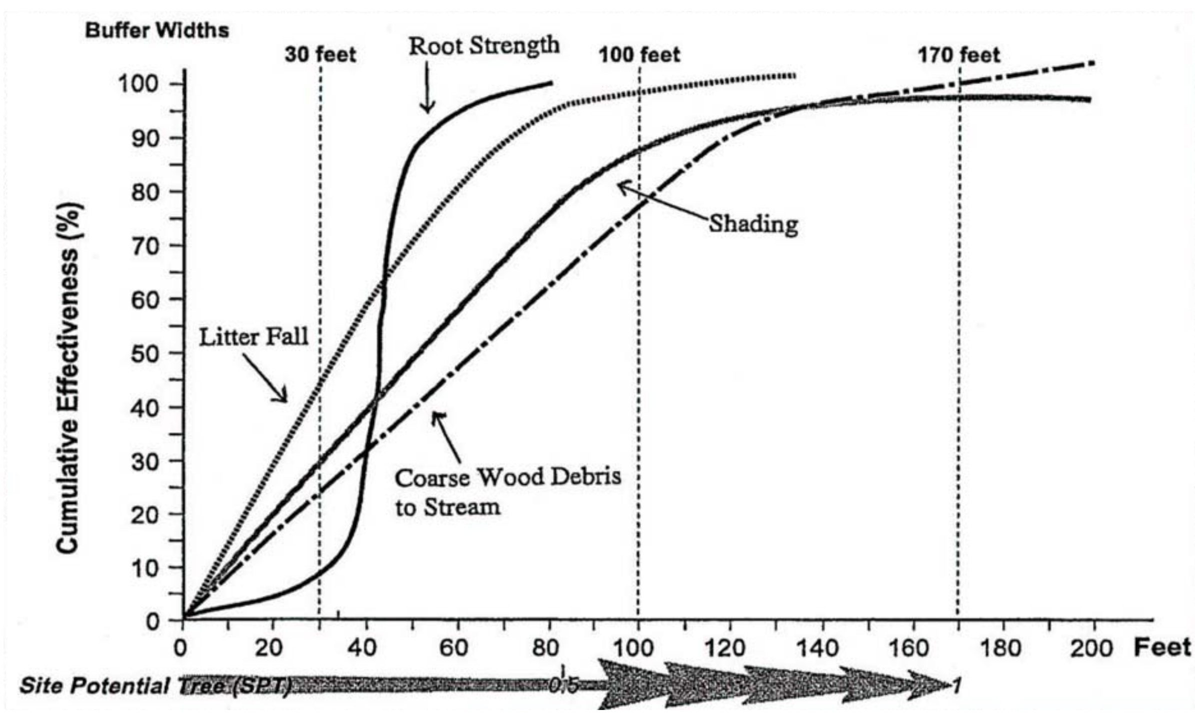


Figure 6 Effects of Riparian Buffer Width on Microclimate (adapted from FEMAT 1993).

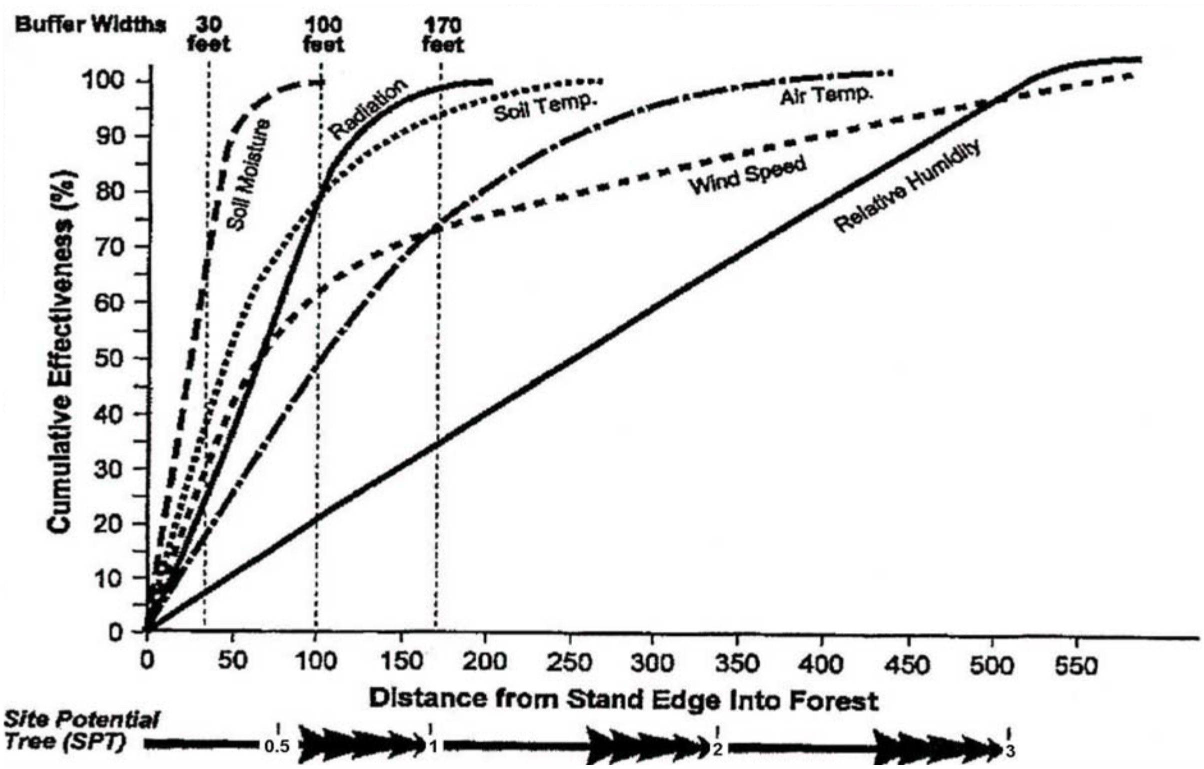
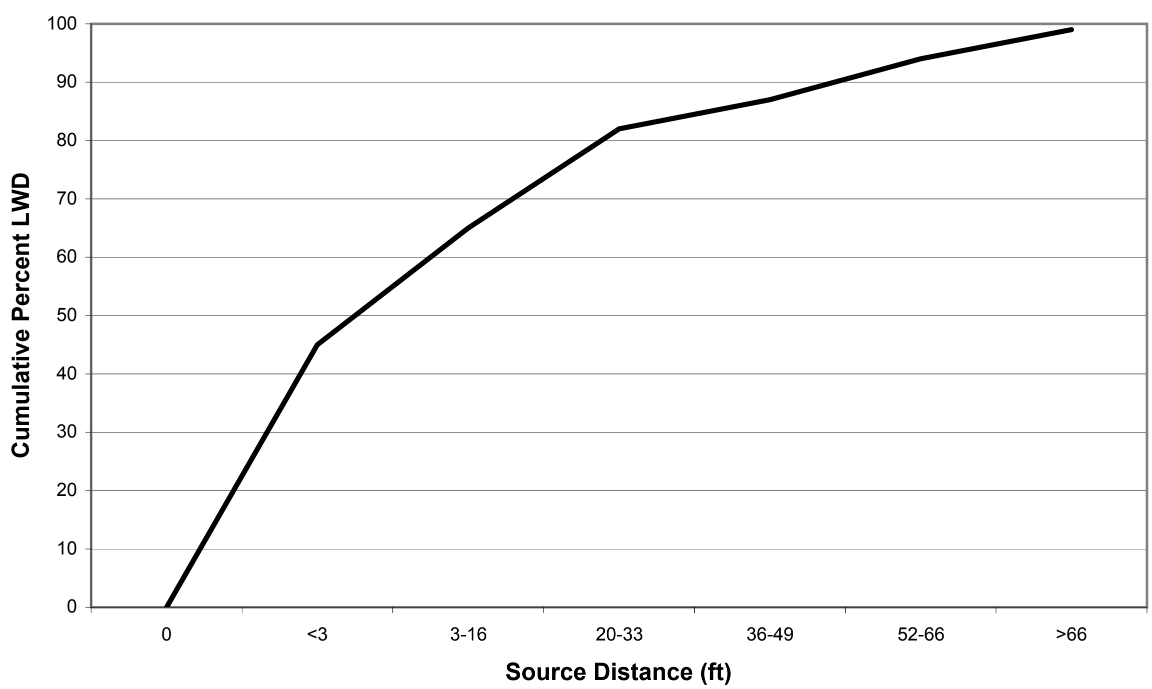
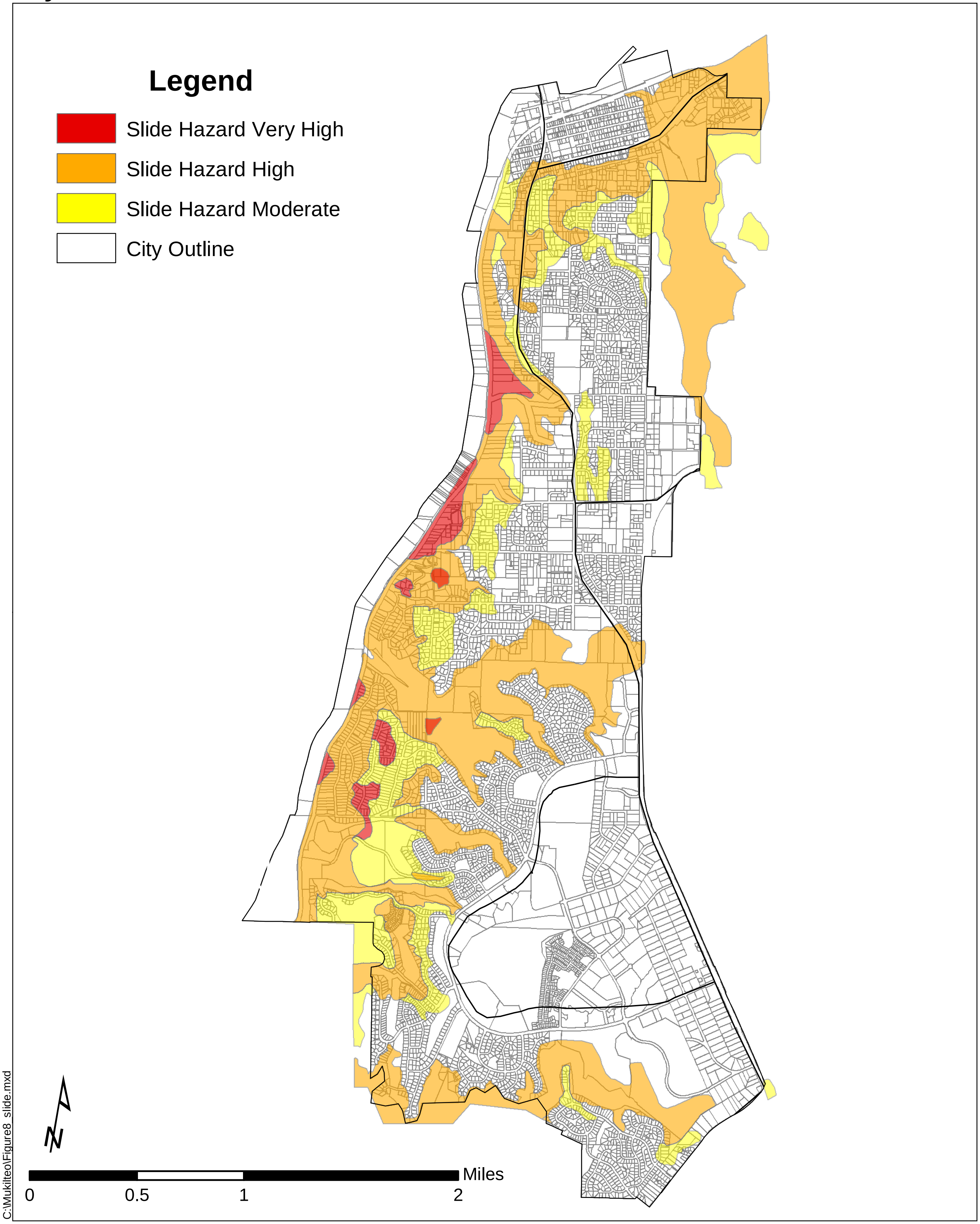


Figure 7 Percent of LWD Contributed as a Function of Distance from Shoreline (adapted from Murphy et al. 1987).



City of Mukilteo Potential Slide Areas



Data Sources: City of Mukilteo, Snohomish County, USGS. (Slope calculation using data from USGS)

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Figure 8